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A TREATISE

ON

ARCHITECTURE AND BUILDING CONSTRUCTION

PREPARED FOR STUDENTS OF
THE INTERNATIONAL CORRESPONDENCE SCHOOLS
SCRANTON, PA.

Volume II

MASONRY
CARPENTRY
JOINERY

WITH PRACTICAL QUESTIONS AND EXAMPLES

First Edition

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MASONRY.

PROVINCE OF MASONRY.

1. **Masonry,** the art of shaping, arranging, and uniting stones or bricks to form the walls and other parts of structures, is one of the most important branches of the building trades.

The province of the mason, while not as extensive as that of the carpenter, is equally as important, especially in cities where the buildings are generally built of brick or stone, thus demanding the employment of masons.

2. Mason work may be divided into two classes: *stone masonry* and *brickwork*, one or the other of which must at some time enter into building construction.

3. Stone masonry may be considered under three divisions: *stone setting*, *stone cutting*, and *stone carving*.

The stone setter builds the stone walls of foundations, and lays the stone in the superstructure.

The stone cutter reduces the stone to the required form, and brings it to the face called for in the specifications for the building.

A knowledge of **stereotomy,** which is the geometry of stonework, as seen in vault, arch, and other complicated construction in stone is necessary to the stone cutter.

The stone carver shapes the capitals of columns and the decorative and ornamental work.

4. Brickwork is really artificial stonework; but owing to the difference in the details of its performance, it has become

a separate branch of masonry known as *bricklaying*, and the men employed in laying the brick are called *bricklayers*.

The ornamental portions of many buildings—cornices, string and belt courses, panels, capitals, window caps, etc.—are now molded of terra cotta, but are set by the bricklayer. Terra cotta has the same composition as brick, but is made of a finer quality of clay and in varied colors. It can be made in large sections, and therefore is more desirable, in certain positions, than brick would be.

5. Plastering is generally considered as a part of the mason's work, and is usually included in the specifications as such. Plastering may either be exterior or interior. At one time, the art of the plasterer was largely in demand for stucco and cement work on the exterior of buildings, but fortunately for truthful expression, this has largely become a thing of the past.

EXCAVATION.

CHARACTER OF SOIL.

6. Nearly all structures, from the four or five room cottage to the massive and towering mercantile building, rest on masonry foundations. If the foundations are insufficient or defective, all the subsequent stonework or brickwork is likely to settle and crack; the failure of the initial or primary part of the work thus jeopardizes whatever follows, by reason of its inability to support the load placed upon it.

7. Before putting in foundations, the ground must be excavated, either for the cellar or for trenches to place the masonry below frost line; but before the excavation is begun, especially if the structure is an important one, the nature of the soil which is to support the foundations should be determined. For this purpose, a 2-inch auger is used—similar to an auger for wood boring—and the boring tests are made from 5 to 10 feet apart, over the entire area of the foundation. The auger brings up samples of the materials, and the character of the substrata is thus determined.

When the importance of the proposed structure requires it, trial pits are sometimes dug from 10 to 20 feet apart, especially where a shelving bed of rock or gravel exists at a comparatively short distance below the surface.

8. The soil or strata usually met with in building operations, may be classed under three divisions: first, *rock;* second, *virgin soil;* third, *made ground.*

ROCK.

9. **Rock,** in its original geological formation, is called **bed rock,** and as a rule, makes the best support for foundations. It requires, however, good judgment to determine its value, and careful handling to secure the best results, for it very often happens within the area of a proposed building—especially if it is to be a large one—that the rock will present uneven surfaces, so that some parts of the foundations will rest on rock and others on loose gravel or clay. The methods followed, where these irregularities of surface are met with, will be found under the heading "Footings."

The sandstones and limestones are often found in strata, beds, or layers, one on top of another. If these layers are not separated by clay, and the beds are even, they make good foundations. The strata or beds of rock may shelve, or dip at varying angles. This formation is especially found in hilly sections. The method of laying foundations when shelving rock is encountered will also be described under "Footings."

VIRGIN SOIL.

10. **Virgin soil** is either clay, loam, gravel, marshy ground, or sand, in its natural condition.

11. *Clay* is the most uncertain of soils, owing to its elasticity, due to being mixed with marl, etc.; its tendency to absorb moisture; and, in many cases, the position of its bed or strata. In dry seasons it is very firm, while in wet seasons it is elastic and unreliable. When the layers of clay are

inclined, the foundation has a tendency to slide, producing results threatening to the stability of the superstructure.

12. *Loam*, or clay mixed with sand and other earthy substances, when compact and of considerable depth, is a good material to build on, providing the structure is not an extremely lofty or heavy one.

13. *Compact gravel*, united with sharp sand, makes the best foundation (except bed rock), and, on account of its being more easily leveled, is much less expensive to build on.

14. *Marshy soils* are formed by the decay of plants, weeds, and other vegetable matter in sluggish water, which, having no current, allows the plants, etc. to take root in the bed. When these plants die, others take their place each year. These successive beds of decayed matter are formed under slight pressure, and have innumerable cavities between them, as would a heap of decayed hay. Sometimes these deposits reach to such a depth that their bottoms have not been reached. Large areas of marshy lands are formed in this way, by the periodical overflowing of rivers, and the rise and fall of the tide along the coast.

15. *Sand* is formed from the decomposition of the older rocks, either by the effects of the weather, the action of heavy rains, the wearing away by running water, or the spontaneous decomposition of the rocks themselves. The particles are carried down to the rivers and there deposited, either in their beds or borne out to the ocean.

The sand usually found in excavations has its origin either as the formations in the beds of ancient rivers that have long ceased to flow, called river sand; or by the attrition or grinding of the rocks themselves during the geological upheavals in past ages. The latter is called virgin, or pit, sand, and has never known the action of water.

Quicksand is a very fine sand, often mixed with clay or loamy material in such proportion that it will retain water until it is perfectly saturated. But by confining quicksand and keeping it dry, or as nearly dry as possible, it may be

excavated or built upon with little more difficulty than common sand. In many cases, quicksands are mixed with a bluish or leaden colored silt or soapstone slime. It is often the case in excavating through quicksand, that beds of this blue marl are found; when wet it is tough and hard, but when dry, crumbles to a powder, and is utterly unfit for foundations. An attempt to excavate in quicksand without previously getting rid of the water contained therein, is almost as useless as to dig in water itself, for the saturated sand will flow into the excavation faster than it can be removed.

16. During freshets, rivers bring down large quantities of soil held in suspension, which is deposited when the waters subside. This formation is called alluvial, from the Latin word *alluvius*, meaning *a washing upon*. The term alluvial is often used to designate deposits that are of yearly recurrence, as the Nile and the Mississippi deltas, although the river bottoms of many streams are originally of alluvial origin. The value of alluvial soil for foundation purposes varies much. In many cases, it consists of a clay formation that is hard on top, especially during dry weather, but soft and unreliable underneath. Heavy buildings should not be erected on alluvial ground without a careful investigation of the subsoil by means of borings or trial pits.

MADE GROUND.

17. **Made,** or **artificial,** ground may consist of various kinds of materials; such as the refuse of cities, earth and other materials removed from cellars and other excavations, the cinders, ashes, etc. from manufactories and furnaces. It should not be built on, if the structure is of importance, without investigating the nature of the subsoil, though for minor edifices a suitable foundation may often be obtained on good made ground.

CONCLUSIONS.

18. From the above description of the various kinds of soil and other materials met with in foundation beds the following practical deductions may be made:

1. It is generally safe to build on bed rock any structure that may be required, providing the foundation beds are kept level.

2. Gravel, even when mixed with small boulders, can also be considered perfectly reliable for any ordinary structure, under usual conditions.

3. Sand will carry very heavy loads, provided it is confined; but great precautions must be taken to properly confine it, and also to keep water, especially if running, from it, as the action of water on the sand would very soon wash it away.

4. Clay, when compact and dry, will carry large loads, but water should be kept from it, both under and around the structure, the foundations of which might otherwise give way, due to the difficulty of retaining the pasty or semiliquid mass formed.

5. A thick, hard, or compact stratum, overlying a much softer one, even silt or quicksand, will often carry a considerable load, the hard stratum floating upon the soft as a raft floats on the water. It is usually better not to break through this hard stratum, as it serves to spread the base and distribute the pressure over a large area. Most of the large buildings in Chicago are built on soil of the above description. The proper way to build on such material will be treated under the heading "Spread Foundations."

6. The silt, slush, and decayed vegetation contained in the marshy lands, especially in the Southern states, are not fit to build on without piling.

19. In all cases, the base of the foundations should be so spread out as to keep the pressure per square foot of base or footings within the safe limit.

Table 1 gives the safe loads that different kinds of earth, rock, etc. will bear. By calculating the weight of a building, from tables and data to be given, the bearing power of the soil it is to be placed on can readily be found.

These calculations for the bearing power of earth, etc. are safe loads, and may be used with confidence.

TABLE 1.

BEARING POWER OF SOILS, ETC. IN TONS PER SQUARE FOOT.

Kind of Material.	Minimum.	Maximum.
Rock, hardest in native bed	300	—
Rock, equal to best ashlar masonry ..	25	40
Rock, equal to best brick.....	15	20
Clay, dry, in thick beds.....	4	6
Clay, moderately dry, in thick beds..	4	6
Clay, soft.....	1	2
Gravel and coarse sand well cemented.	8	10
Sand, compact and well cemented....	4	6
Sand, clean, dry.....	2	4
Quicksand, alluvial soils, etc.....	0.5	1

CELLARS AND FOUNDATIONS.

AREA AND DEPTH OF EXCAVATION.

20. In cities and towns of good size, it is customary to have the building lines laid out by an engineer; but in country work—remote, possibly, from professional talent of that sort—the architect himself is often called upon to lay out the lines of the building.

The plans of the building show the area, and the sections or elevations show the depth of the excavations.

The figures on the foundation plan should be carefully checked, as any error made at this stage of the work is difficult to rectify afterwards.

The outside lines of the building proper should be run first, and stakes driven at each corner or angle. Cords should then be stretched from these around the foundation site, and the lines for the footing courses measured off according to the distance the footings project beyond the foundation walls. By driving stakes also at the corners of the footing courses, and stretching cords from each

footing-course stake to the next, the area to be excavated can be ascertained.

The portion of the building required for cellar, as well as the footing courses required for the portion having no cellar, must be excavated to the proper depth.

21. The usual depth of cellars for dwelling houses should not be less than 8 feet from the under side of the first floor beams, and more where the house is to be heated by a furnace, in order to give sufficient height above the furnace to allow a proper ascent to the hot-air pipes. For store, office, and manufacturing buildings, the depth is greater, varying according to the nature of the business carried on, or the requirements of the occupants. In some of the large office buildings in cities, there are no less than three cellars: basement, cellar, and subcellar, and the excavations vary from 25 to 60 feet in depth.

22. Care should always be taken, in case there is no cellar under a building, to have the excavation in the trenches go down below the frost line. This depth varies in different parts of the country, but in the Eastern and New England states 4 feet is considered sufficient for ordinary buildings, if the subsoil is satisfactory. If the foundations are not started below the frost line, the alternate freezing and thawing of the earth tends to throw the walls out of plumb, and will eventually destroy them, and also rack the superstructure. This subject will be more fully explained under "Footings."

23. When the nature of the soil is such that piles must be driven to carry the building, it is customary to excavate to water level before driving the piles. This is done in order that the heads of the piles may be cut off at the water line, it being necessary that the piles be wholly under water to prevent decay.

24. In excavating cellars, it is customary to leave a *runway;* that is, a part of the ground is sloped down from the bank to the cellar bottom, for the more convenient removal

of the excavated material. In very deep cellars covering a large area, this runway is usually built of heavy plank supported on wooden beams and posts.

PROTECTION OF EXCAVATIONS.

25. Especial care should be taken, especially in cities, to properly protect the adjoining property, sidewalks, etc. from injury by the caving in of the bank during excavation.

To guard against this, the banks or sides of the excavation are sheet piled, as shown in Fig. 1.

Sheet piling consists of a plank cut to a point at the lower end, placed closely in line, and driven into the ground against

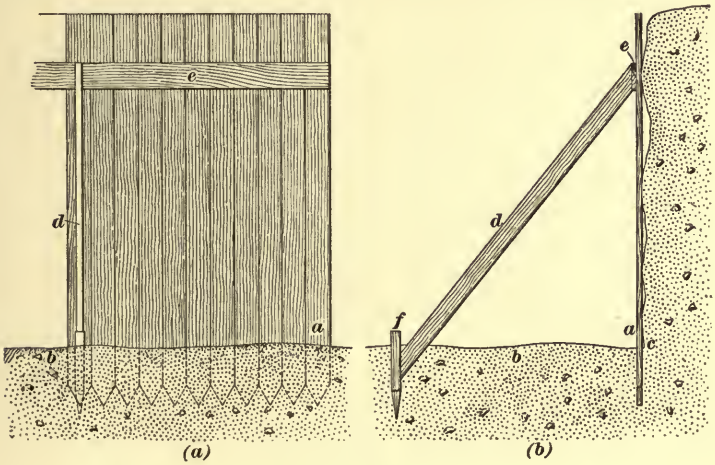


FIG. 1.

the bank of the excavation, as shown at (*a*), Fig. 1, which is a front elevation of sheet piling. At *a* is shown the piling driven into the cellar bottom *b*, against the bank of the excavation. At (*b*) is a section across the piling to show the braces *d* placed against the batten *e* to retain the piling in place against the earth pressure at the top. The stake shown at *f* is driven in to keep the brace *d* from slipping. These braces are usually spaced about 10 or 12 feet apart, and are necessary when the excavation is a deep one.

26. When the foundations of a new building go below those of the adjoining property, the adjacent walls must be **underpinned,** the method of doing which, will be described in a subsequent section.

REMOVAL OF MATERIAL.

27. Blasting.—In many cases, when rock is reached, blasting must be resorted to; in cities, this is a separate branch of contracting, and the blasting is usually let as a subcontract.

28. When a blast is to be made, a hole to receive the powder is first drilled in the rock by hand or power drills; these holes vary in diameter from ½ inch to 2½ inches, and in depth from a few inches to many feet, while the direction varies according to the dip, or slope of the rock.

The borer or jumper used in drilling is a steel-pointed bar. Generally one man, in a sitting position, directs the drill, turning it after each blow to keep the hole cylindrical, occasionally pouring in water, and cleaning out the powdered stone with a scraper. A small rope of straw or hemp is twisted around the drill or jumper at the top of the hole. One or two men strike the jumper with sledge hammers.

When a sufficient depth is reached, the hole is dried by means of a rag on the end of a wire, and the charge of powder put in; a small rod of copper, called the needle, or nail, is inserted so as to reach the bottom of the charge. The remainder of the hole is then filled up with dry sand or tough clay, which is called tamping; if wadding is used, it is firmly rammed in by means of the tamping bar, which is a copper-faced punch of such size that it nearly fills the hole, and has a grove in it to receive the nail. This operation requires great care because of the danger of producing sparks by striking the rock with the tamping punch. Powder is now poured in the hole, and the blast is exploded by a slow match connected with it.

An improvement on this method of firing, consists in the use of a fuse; this may be described as a rope or hose, containing an inflammable composition. A suitable length of

the fuse is placed in contact with the charge before tamping, and carried up to the mouth of the hole. On being lighted, it burns at the rate of 2 or 3 feet a minute, giving time for the blasters to get to a safe place before the explosion occurs.

Electricity is now used very extensively for the purpose of firing the charge, especially if the explosive is dynamite. A dynamite cartridge is placed in the hole, but no tamping is required; the cartridge is connected by two insulated wires with an electric battery, and on making the connection, by pressing a button on the outside of the box containing the battery, the charge is exploded.

In order to confine the pieces of rock that would otherwise be shot into the air after an explosion, and prevent damage to adjoining property, or possible loss of life, a number of heavy logs are placed over the rock to be blasted, and sometimes bound together by a heavy chain. The weight of the logs keeps the fragments of stone, etc. from flying when the charge is exploded.

29. Where extensive blasting operations are going on, rock-boring or drilling machines are used, insuring considerable saving in time and labor over the old method of hand drilling.

In these machines, the drill is repeatedly driven against the rock, either by compressed air or steam, the drill also being made to rotate slightly at each blow. The work of drilling can be done by the use of rock drills at least one-third cheaper than by hand power. There are several different machines; the Rand, Ingersoll-Sargeant, Burleigh, and Diamond are considered the best.

30. Wedging.—Where rock must be taken out so close to existing walls that injury might result from blasting, the operation of *wedging* is resorted to. This consists of breaking up the rock with wedges, which are of steel, about 8 inches long, with wire wound about them so as to form a handle. A workman holds the thin edge against the rock, and another man strikes repeated blows on the wedge with a hammer until the rock is split or broken.

When the rock breaks easily and runs in layers with defined

seams between them, large quantities may be cheaply gotten out by this means; but it is a slow and expensive process if the rock is hard and lies in large compact masses.

CESSPOOLS.

31. In cities, drainage by regular sewerage is provided, but in the country, cesspools are usually built to receive the sewage from the building.

In many cases the old leaching cesspool, or dry well, is still adopted. If the house is to be supplied with water from a town or city service, or from springs higher than the building, and at a considerable distance, the leaching cesspool may be tolerated, on account of its low cost, but only so long as the circumstances require. If, however, water is to be drawn for use from any well within 300 feet of the proposed cesspool, and on the same or a lower level, no cesspool should be built that will allow its contents to soak into the subsoil.

32. If there is no danger that the drinking water may be contaminated, the cesspool may be excavated in a circular form from 8 to 12 feet in diameter, and usually of a depth sufficient to reach an absorbent stratum, the sides being lined with a dry wall of stone or brick, and the top drawn over in the shape of a rude dome, which should be covered either with an iron cover or a flat stone. In sandy or gravelly soils, such a cesspool will dispose of the waste liquids of the house for a long time, but in the course of years the earth around it becomes permeated with the solid matter in the sewage, and a new cesspool should be dug.

In very clayey soils no leaching or absorption of the sewage by the soil takes place, and the cesspool fills up like a tight cistern, one of ordinary size overflowing after a few days' use.

As the simplest way of getting rid of the sewage when the cesspool is full, is to pump it out at intervals through a hole in the cover, it is well to make proper provision for this when the cesspool is built.

33. To avoid the choking of the house drains by the filling of the cesspool, it is customary to provide an overflow

through which the liquid can, if necessary, escape over the surface of the ground.

An automatic arrangement may be used instead of a surface overflow, consisting of a permanent outlet, formed by a series of open-jointed pipes, laid 8 or 10 inches beneath the surface; the liquid exuding from between them will be absorbed, partly by the porous loam which always forms the upper stratum, and partly by the roots of grass or other vegetation.

DISPOSAL OF SEWAGE.

34. An efficient system of subsoil irrigation and drainage must consist of two parts: the tight cesspool, or tank, where the waste matters from the house are retained until they are decomposed, and the network of pipes which receives the sewage from the reservoir and distributes it into the ground.

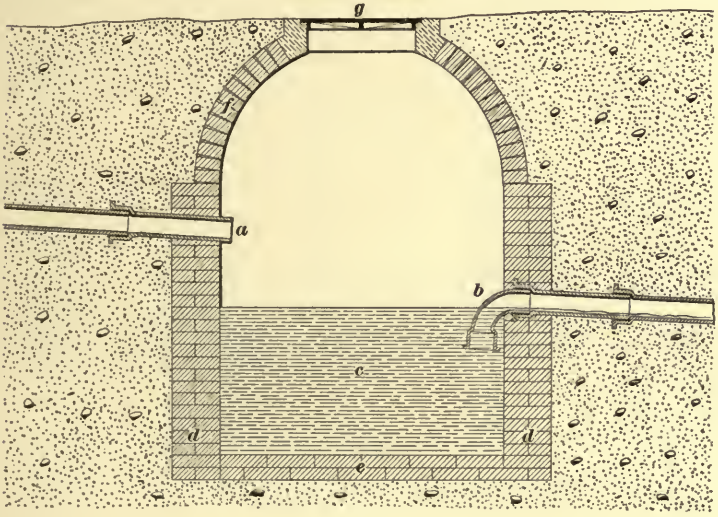


FIG. 2.

The cesspool—of which Fig. 2 shows a section—should be built of hard brick laid in cement, about 6 feet in diameter and 5 feet deep from the mouth of the outlet *b*. In the figure, *a* shows the sewer pipe conveying the sewage from the house; *b* is the outlet pipe connecting with the distributing

pipes; *c* shows the liquid sewage; *d* is the 8-inch wall, *e*, the 4-inch bottom, *f*, the 4-inch dome, and *g*, the manhole, 18 or 20 inches in diameter. This manhole should be covered with an iron grating. The main drain should enter the cesspool just above the water line. The outlet pipe should have a quarter bend cemented in where it runs out of the cesspool, and should be laid at a very gentle pitch, with branches as indicated in Fig. 3. This pipe should be made of vitrified earthenware, laid with the hubs towards the upper end, and having a Y inserted alternately with the straight pipe, to connect with agricultural tile forming the branches.

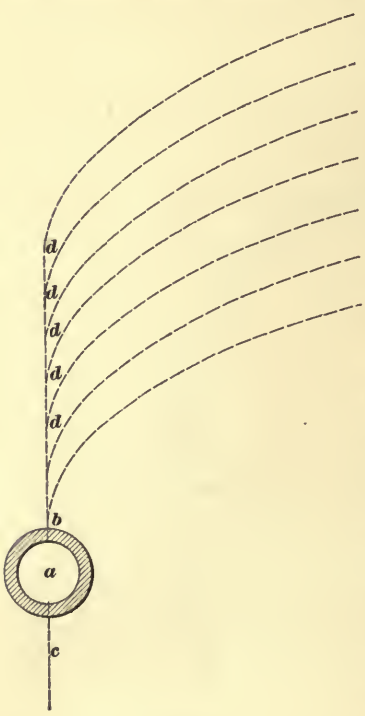


FIG. 3.

In Fig. 3, *a* shows the cesspool, while *b* shows the location and position of the 4-inch outlet pipe; *c* is the sewer pipe from the house, and *d*–*b*, etc., the 2-inch agricultural drain pipe.

The tiles forming the lateral branches should be laid ½ inch apart, and a piece of paper should be put over the joint to keep the earth from sifting in and obstructing the flow. The end of the main line should not be crossed, but a 2-inch reducer should be put in, so that the line of lateral branches may be continued if necessary.

For any ordinary dwelling house, inhabited by a family of six to eight persons, 500 feet of lateral outlet is enough.

Care should be taken to grade the earth away from the building, and there should be a very decided pitch in every direction, in order to carry off the water.

CISTERNS.

35. Cisterns are often necessary where springs are scarce and wells are not available.

A cistern should be built in much the same manner as the cesspool shown in Fig. 2, but should be larger; about 8 feet in diameter and from 6 to 8 feet deep. Cisterns are usually built of brick laid in cement and are made waterproof by covering both the inside walls and floor with an inch of pure Portland cement. The manhole should have a pump set in it.

The roof leaders are all run into an earthenware pipe connecting with the cistern, and a 4-inch outlet pipe, similar to the pipe shown in Fig. 2, is provided to carry off surplus water.

36. It is sometimes found, during excavations in shelving rock, especially if the foundations are on a sloping hillside, that a spring, or springs, are encountered, the water from which will run into the cellar. This water should never be allowed to run through open channels; but a shallow well about 3 feet deep should be made just beyond where the spring issues. A channel should then be made

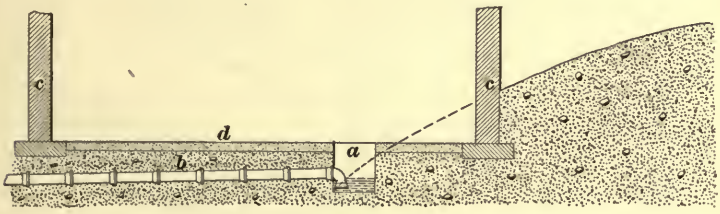


FIG. 4.

and a pipe laid, with tight joints, leading to a proper place of disposal. If a gravel bed is in the neighborhood, the pipe may be carried to that and emptied into a pit filled with loose stone; from which it will percolate through the gravel. If the spring water is good for drinking, the pipe may run into the cistern, should one exist.

Fig. 4 shows the arrangement: *a* is the spring and well; *b*, the pipe under the cellar bottom; *c*, *c*, the cellar walls; and *d*, the cellar bottom.

PROTECTION OF FOUNDATION WALLS.

37. One of the dangers that may be met with during the excavation is the presence of a clay bank between limestone, sandstone, or sand beds. These beds being watertight, that is, not permitting rain water to penetrate their thickness, currents or sheets of water flow over them, which may cause great derangement to the foundations, especially if this clay bank or stratum abuts against the foundation walls. Rain which will easily penetrate the gravel or loam above, or percolate through the crevices of the rock, will be arrested by this clay bank; little by little it will form cavities and produce a concealed current. If the cellar wall extends below this current, the water will penetrate it, and fill the cellar.

In this case, it will be necessary to turn aside this sheet of water by means of a drain, as shown at (*a*) in Fig. 5. Here *a b* is the gravel, sand, or loam bed that water can penetrate;

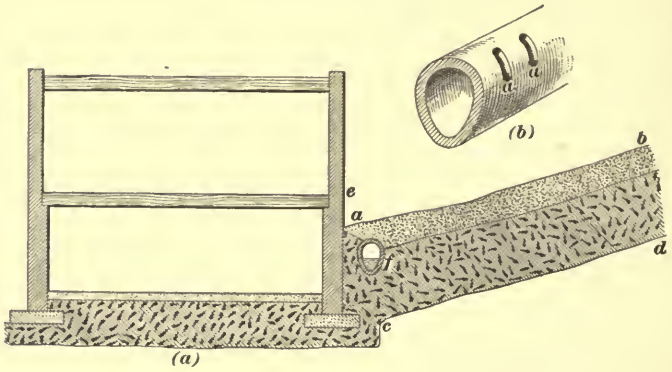


FIG. 5.

c d, the clay bed on top of which water collects after every shower, which would be stopped by the foundation of the cellar *e*, and would soon penetrate it; *f* is the transverse drain with openings upward to receive the water, thus leaving the wall *e* dry. Fig. 5 (*b*) shows a view of part of the intercepting drain; *a*, *a* are openings for the water to enter.

38. If foundations are laid in open clay, another difficulty is often met and must be guarded against.

Clay banks may slip, when their slopes present such a section as shown in Fig. 6, where *a* shows the rock bed under the clay bank or stratum *b*, and *c* is the gravel or loam on top of the clay. The rain water accumulating above will pass at *e* under this bank, and if the rain continues long will

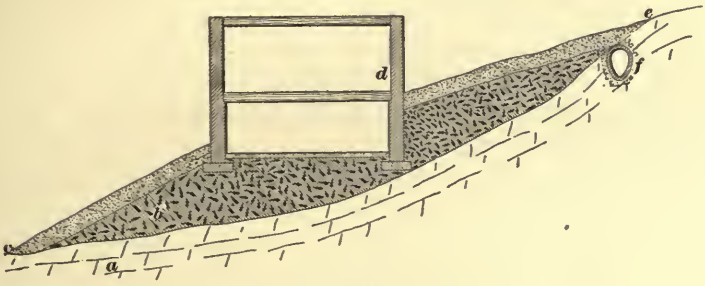


FIG. 6.

form from *c* to *e* a thick, soapy bed so that the clay bank may slip by its own weight especially if that weight be increased by that of the building *d*.

This danger may be averted by building the drain *f* at the upper end of the clay bank *c e*, to intercept the water running between the clay bank and the ledge of rock. It would be well also to extend the foundation wall at *d* down to the rock, thus presenting a solid face to the pressure of the clay bank, and preventing absolutely the upheaval of the cellar floor and bulging of the wall *d*.

39. Excavation is usually measured by the cubic yard of 27 cubic feet, and the price paid varies according to locality, nature of the soil, distance material excavated must be hauled, and disposition to be made of it.

Twenty-four cubic feet of sand or 17 cubic feet of earth or clay, when comparatively dry, will weigh a ton.

One cubic yard of earth before removal will occupy about 1½ cubic yards when dug, contains 21 struck bushels, and is considered a single load.

FOUNDATIONS.

FOOTINGS.

PURPOSE OF FOOTINGS.

40. If a man stands on soft mud, marshy ground, or quicksand, he sinks to a greater or less degree, proportional to his weight. If, however, he stands on a plank or wooden platform, or on a post, or posts, driven through the mud or marsh to firmer ground, his weight is distributed over a larger area in the first case and carried down to a better foundation in the second.

It is similar with the footings of buildings. By spreading the load, or weight of the structure, over a larger area or bearing surface, the weight of the building is more evenly distributed, and the likelihood of a vertical settlement, due to the compression of the ground, is much diminished. For this reason, the higher and heavier the building is to be, the wider and deeper the supports or footings for the foundation must be; and if extremely soft or yielding ground is encountered, piling should be resorted to in order to carry the weight of the building to a more solid base.

41. Footings may be of iron, timber, large flat building stones, laid directly on the ground or on a bed of concrete, or they may be of concrete alone, or concrete and "stepped-up" brickwork. Where piling is used, heavy capping timbers are often placed on the heads of the piles, with either stone or concrete footings; or large footing stones may be laid directly on the piles.

TIMBER FOOTINGS.

42. Timber is often used for footing courses where a large bearing surface can be obtained and is necessary; providing, always, the timber can be kept from rotting. In some cases the timber is charred on the outside, and in other cases it is coated with asphalt. If the ground is continually wet, there is little to fear, as timber will not

decay when kept saturated with water; but when alternately wet and dry, unprepared timber cannot be depended upon.

The best method of placing plank under walls for footings is to use $3'' \times 12''$ plank cut in short lengths and laid crosswise in the trench. A layer of plank of the same size is then laid lengthwise, followed by a third layer again placed transversely. As shown in Fig. 7, *b* is the *stone* footing resting on the footing planks *a*, and carrying the stone foundation wall *c* between the walls *d*, *d* of the trench.

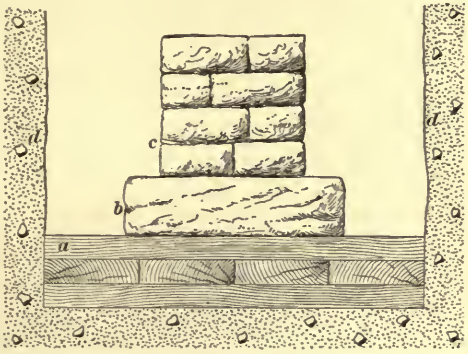


FIG. 7.

CONCRETE AND STONE FOOTINGS.

43. Fig. 8 shows a 20-inch brick wall *b*, on a concrete footing *a*, 20 inches thick and 3 feet wide.

Figs. 9 and 10 show the concrete base *a*, and stepped-up brick footing courses *b*. In Fig. 9, each course of brickwork

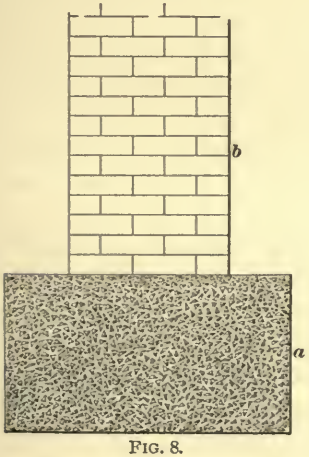


FIG. 8.

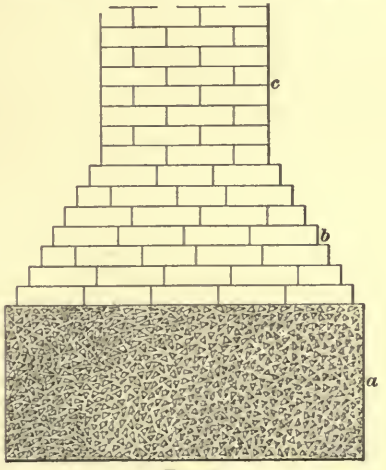


FIG. 9.

sets back 1½ inches for each course, while in Fig. 10 the courses are set back 3 inches for each two courses. At *c* is

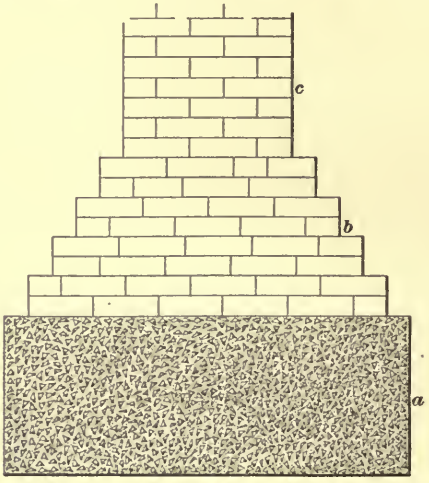


FIG. 10.

shown a 20-inch brick foundation wall resting on the stepped-up brick footing.

44. Fig. 11 illustrates stone footings *a*, composed of three courses of flat stone, each course being 8 inches thick. The top course has a projection of 6 inches on each side of the 20-inch brick foundation wall *b*, and the middle and bottom courses each project 3 inches, making the width of the bottom stone 3 feet 8 inches.

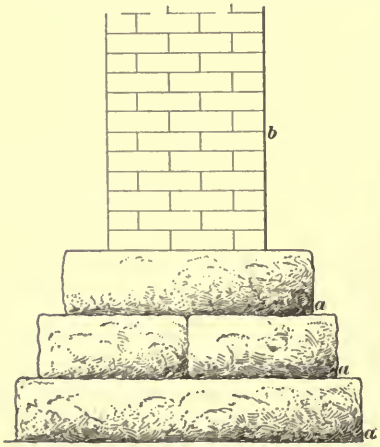


FIG. 11.

Fig. 12 shows a stepped-stone footing *a*, similar to those shown in Fig. 11, but supporting a 24-inch foundation wall. Each base course advances in stages of 3 inches.

Fig. 13 shows a footing consisting of a single course of stone *a*, 8 inches thick and 2 feet 4 inches wide, carrying the stone wall *b*, 20 inches thick.

FIG. 12.

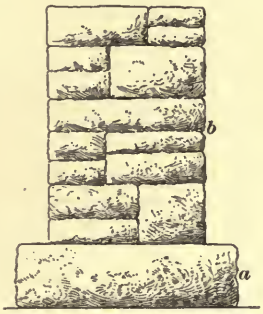


FIG. 13.

45. As a general rule, concrete, when of sufficient depth and width, and when properly made and laid, makes the best of footing courses.

Concrete, for footings, should be made of 1 part good cement, 3 parts clean, sharp sand, and 5 parts sharp, broken stone. In very important work, such as bridge piers, and the footings of very high buildings, chimneys, etc., a proportion of 1 of cement, 2 of sand, and 4 of broken stone is generally used. The New York building laws call for 1 of cement, 3 of sand, and 5 of broken stone.

None of the stone used in making concrete should be larger than will go through a 2-inch ring. In localities where stone cannot readily be obtained, broken brick or terra cotta may be used in the same proportion as stone, taking care to use good hard-burned material.

Well broken foundry slag and scoriæ, steam-boiler ashes from anthracite coal, and clean-washed gravel, mixed in the proportions given, make good concrete, though gravel, being rounded and smooth stone, does not adhere to the mortar as well as broken stone, slag, brick, or scoriæ does.

46. In preparing concrete, the material should be worked on a platform of boards, with sides about 10 inches high, battened on the back and laid on the ground near the work. The platform is necessary in order that no loam or clay may contaminate the concrete, the effect of this being a loss of strength in the concrete, as the clay adheres to the stone and prevents close contact with the mortar. The sand and cement should first be thoroughly mixed by shoveling them together while dry, at least twice, so that there will not be an unequal proportion of sand to cement in different parts of the heap. The broken stone, or whatever material is used for the *aggregate* (as the stone, slag, or other coarse material is called), should then be added, the mixture being kept wet all the time and thoroughly shoveled together, so that every portion of the stone or other material may be perfectly coated with the mortar.

When extensive works are carried on, the concrete is often mixed by the wet, or machine process. The cement, sand, and broken stone, or other aggregate, are placed in a cylinder of iron, or wood lined with iron, containing a long auger-like screw, laid longitudinally, over which a perforated pipe sprinkles water into the trough, or mixer. By the revolution of the screw, the material is thoroughly mixed.

No concrete should be made unless it is to be used at once, because the cement, forming its most essential part, sets or hardens quickly, and if it sets before being placed in the footing trenches, it is valueless.

47. As soon as the concrete is thoroughly mixed, it should be conveyed to the footing trenches and put down in layers of from 6 to 8 inches thick. As each layer is put down, the concrete should be well rammed with a wooden rammer, until the cement flushes, or shows on top of each layer. This method causes the different layers to unite, and make one solid, homogeneous mass, and is preferable to throwing the concrete from a platform into the trenches, as by the latter method the concrete does not become consolidated.

Should one layer have become partly set before another layer is put down, the concrete should be swept clean, scratched with a rake, and well wet before the next layer is put in place.

Sometimes it becomes necessary to lay concrete in running water, and unless some means is devised to protect it during the laying, the water will wash the cement away from the concrete, and weaken it. By making large bags of oiled cotton and filling them with concrete, and then lowering them into the excavation, the concrete will set before the water can wash the cement out.

48. As before stated, quicksand, when confined, can be safely built upon. Fig. 14 shows a method of confining quick-

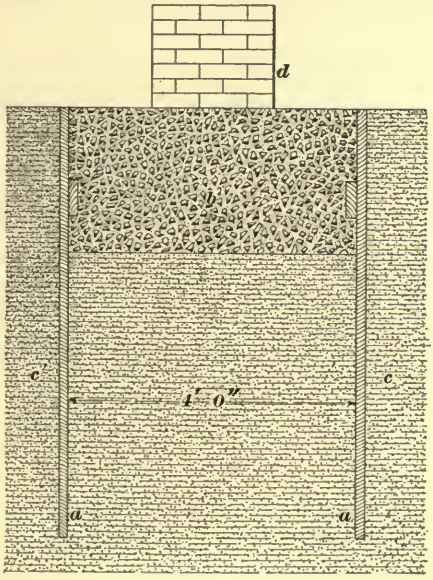


FIG. 14.

sand by sheet piling, and placing concrete between the piling. The sheet piling shown at *a* is placed, in this case, 4 feet apart; the concrete shown at *b* is 2 feet thick

and extends the full width of the piling; the quicksand, through which the sheet piling is driven, is shown at *c*, and the 20-inch brick foundation wall, at *d*.

49. Fig. 15 gives an example of a footing composed partly of timber. This was placed near the water line of a marsh in New York state, to carry a large factory building 50 ft. × 80 ft. and 40 ft. high. The soil is a stiff, black muck, and at a depth of about 5 feet, water-soaked sand was found. After the trenches were dug a bedding of concrete *a*, 12 inches thick, was laid. On top of this, 2-inch spruce plank *b* were placed crosswise, followed by 8″ × 8″ timber *c*, laid parallel with the trenches, filled in between with concrete. On this are laid the base stones *d*, and on top of these is built a 20-inch foundation wall *e*. The trenches on each side of the wall were filled in with sand, rammed down, as shown at *f*.

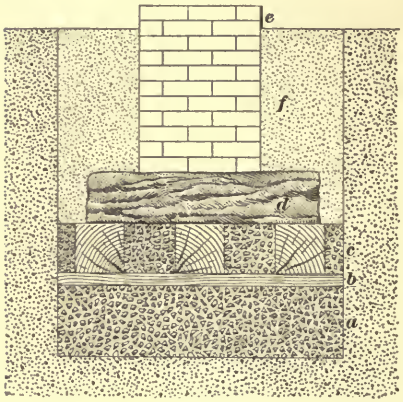


FIG. 15.

The factory has an engine, shafting, boiler, and machinery, and over one hundred operatives are employed. No settlement has occurred, though the factory has been built several years.

50. **Stone-footing** courses should be laid with large flat stones not less than 8 inches thick. If more than one course is laid, as shown in Figs. 11 and 12, the joints should never come over each other, as this would defeat the object of bonding, which is to firmly tie together the parts of the wall.

All stone footings should lie on their natural, or quarry beds, and all the joints and spaces between the stone must

be well filled with mortar, because the mortar acts as a bedding between the stone, and unless this were interposed, the uneven pressure of one stone on another might cause a fracture of the lower one and produce settlement.

51. All footing courses, as indeed all mason work below ground level, should be laid in cement mortar, although in dry, well drained soil, lime and cement mortar may be used. The usual proportion of cement and sand for cement mortar is 1 part of cement and 3 parts of sand, and should be used immediately after being mixed. The proportions of cement and lime mortar are 1 of cement, 1 of lime, and 3 of sand. The above proportions are those given in the building laws of New York, Chicago, and Boston, and have been found to be suitable for general mason work.

52. Stepped-up brick footings are often used, having concrete and stone bases, as shown in Figs. 9 and 10. The pyramidal form of stepped-up brickwork carries the load of the superstructure more evenly to the footings and reduces the risk of settlement or fracture. This form of footing is used very extensively for piers supporting iron columns. Nothing but good, hard, well burned brick should be used; and they should be laid in cement mortar, and should break joints—that is, no two joints should come over each other.

FOOTINGS ON ROCK AND GRAVEL.

53. In placing foundation footings on rock, it is sometimes found that some portions of the footings will rest on the rock, and others, owing to the diversified character of the surface, will rest on clay, sand, or gravel. This settlement of the foundation walls—and as a necessary sequence, that of the whole building—will then be uneven, as the walls resting on the rock will not settle, while those resting on the sand, gravel, or clay will, by compressing the material on which they are carried.

Fig. 16 shows the method used to obtain equal settlement. At (*a*) is shown the rock and gravel before leveling or excavating; *a* indicating the clay or sand, and *b*, the rock. It is customary to remove the rock to a certain level, as shown in

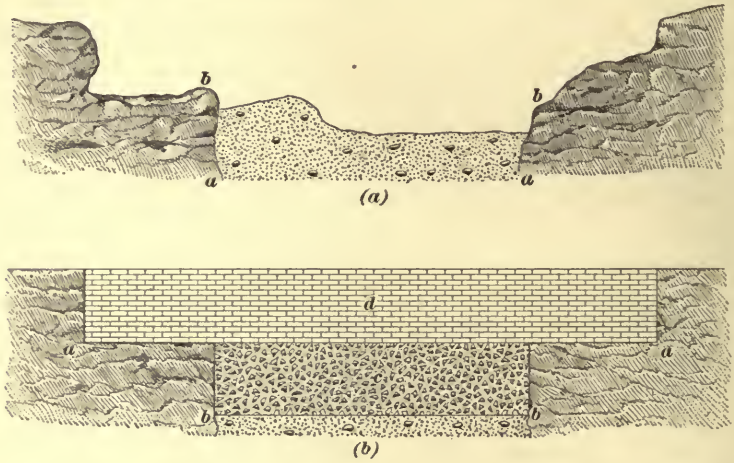


FIG. 16.

(*b*). The softer soil *b* is then removed and leveled off, as at *b b*, and a bed of concrete about 3 feet thick, as shown at *c*, is then put down, the concrete being brought to the level of the rock, and on this the brick or stone foundation wall *d* is built.

54. It is not considered necessary, on solid rock, to have the footing bed cut level over its entire surface, nor even cut into a series of horizontal surfaces resembling steps, as is frequently done in softer soils, which method costs a great deal of time and money; but it is necessary that the surface of the rock shall be so roughened that the possibility of the footing slipping on its foundation will be prevented. After this is done, concrete may be put in to bring the foundation to its proper level. When the structure is three or four stories in height, stone or brick may be used in place of concrete, but a concrete base is usually considered preferable.

FOOTINGS ON SLOPING GROUND.

55. Footing courses built on slopes—especially of clay—are always likely to slide; this may be avoided by cutting horizontal steps in the slope as shown in Fig. 17, where the slope *e f* is stepped off, as shown at *a*, in order that the footings *b* may have a horizontal bearing. These footings may be of either stone or concrete, but when the former material

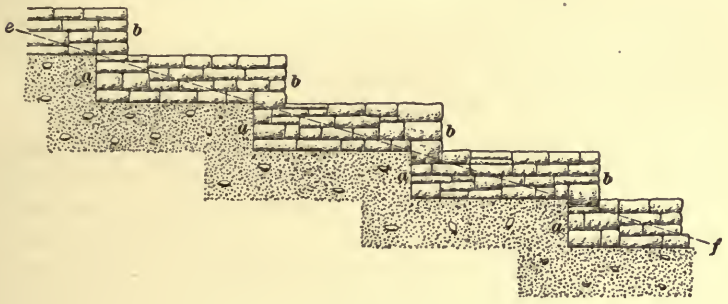


FIG. 17.

is used, great care must be exercised to secure a perfect bond at the stepping places, and the foundations should be laid in as long sections as possible.

SPREAD FOOTINGS.

56. It is often found that compressible soils, even alluvium and soft clay, will bear from 1 to 2 tons per square foot with but little settlement, and under a steady load, this settlement is in most cases uniform. It is very often cheaper, therefore, to spread the foundation over a large area, than it is to drive piles.

In Chicago, for example, the subsoil is of blue clay, found from 5 to 8 feet below the street grade. This clay bed, when below the level of ground or drainage water, becomes quicksand or blue mud, and has a bearing capacity of only a little over 1 ton per square foot, so the heavy weights of the high buildings are carried on spread foundations. This

plan is usually adopted in the Chicago soil, because the quicksand, or muck substratum is of great depth, and piles driven through the stiff upper stratum sink 2 or 3 feet at every blow of the hammer, and are held solidly only at the top and the bottom, if that is reached.

57. Spread footings may be built either of concrete with iron tension rods, or with a base of **I** beams, or railroad iron, bedded in concrete; and in some cases, the footings are composed of timber and concrete. In cases where the requisite height can be obtained, concrete spread foundations, composed of Portland cement, with twisted iron bars for tension members, have many qualities to recommend them. These footings are not expensive and are very durable, as the iron or steel is so embedded in the concrete that it cannot rust, and hence there is no possibility of deterioration. Besides, the entire tensile strength of the rods is utilized, and as they are held continuously along their entire length by the concrete as a screw is held by the nut, they can neither draw nor stretch unless the concrete extends also.

58. Fig. 18 shows the section of a concrete and twisted-iron footing, where *a* is the concrete base, and *b* the twisted-iron tension bars, running both longitudinally and transversely. The base stone is shown at *d*, and the brick pier or superstructure at *e*. In building these footings, a layer of concrete, made in the proportion of 1 part cement, 3 parts sand, and 5 parts stone, should first be laid from 3 to 6 inches thick, and the first tier of longitudinal bars laid on this and tamped down. The transverse bars are then laid, and another layer of concrete, 4 inches in

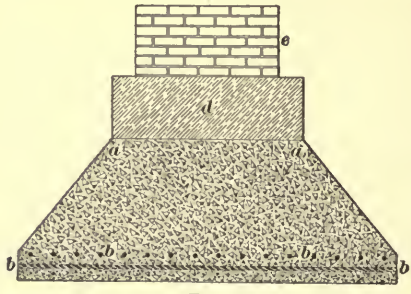


FIG. 18.

thickness, should be spread; as many courses as are necessary are thus laid.

Footing courses laid in this manner, 8 feet square, 2 feet thick, with stone footings 4 feet square and 16 inches thick, the bars placed 6 inches from centers and made of 1 inch square iron, will carry 60 tons to the square foot.

This form of construction has been patented, and the rights are owned by Ransome & Smith, of New York and Chicago. When twisted bars are used, a royalty must be paid, but even then it is a cheap footing when the ultimate strength obtained is considered.

59. When buildings are on solid ground, it is claimed that steel or iron footings are cheaper than masonry. Owing, however, to the danger of rusting in steel, it is doubtful if steel footings are as durable as those composed of masonry.

In preparing the footings for laying steel beams, the bottom of the pier must first be located, and the ground carefully leveled. When the ground is of soft material and the sides of the excavation are in danger of falling in, heavy planks or timbers should be set up and fastened together at the corners, to hold the concrete in place and prevent its spreading before it is thoroughly set. Portland cement concrete, made of 1 part cement, 2 parts sand, and 4 parts broken stone, should then be laid in layers, of from 6 to 12 inches thick, according to the weight on the footings. If this concrete bed is 12 inches thick, it should be made in two layers. On the concrete, the iron or steel beams should be bedded in mortar made of 1 part Portland cement and 2 parts sand, so as to make them level and in line with each other.

All iron or steel beams should be thoroughly cleaned with wire brushes, and when absolutely dry, painted with metallic paint, or heated and coated with two coats of hot asphalt. The beams should be very carefully examined before covering them with the concrete, and if any of the paint or asphalt has been scraped off, the coating should be renewed. Every possible means should be used to keep the beams

from rusting, for when unprotected, they rust very quickly.

60. The **I** beams may be variously spaced from 10 to 20 inches between centers, according to the height of the beams, thickness of concrete, and weight per square foot of superstructure, and should be held in place, relative to each other, by means of separators and tie-rods. They should not be spaced so far apart as to crush through the concrete, and there should not be less than 2 inches of space left between the edges of the flanges, so that the concrete filling may be placed between the beams. This concrete filling should be made in the same proportion as the concrete bedding, but the stone used for the aggregate must not be larger than will go through a $1\frac{1}{2}$-inch ring, and the concrete should be well rammed so that no voids will be left. It should also be carried not less than 3 inches beyond the sides and ends, and kept in place by planking or timbers.

61. If there is more than one tier or layer of beams, the top of each layer is sometimes leveled, after the cement has been rammed in place, with cement mortar, made of 1 part Portland cement and 2 parts sand, laid about $\frac{1}{2}$ inch thick over the top of the highest beam, and on this the next layer of beams should be laid.

Some writers suggest that two thicknesses of tarred felt be laid in hot asphalt on top of the concrete before the beams are laid, and on this $1\frac{1}{2}$ inches of 1 to 2 cement mortar, on which the beams should be placed. The same authorities also recommend that the whole exterior of the footing be covered with two coats of hot asphalt put on over the cement.

The iron base plate or stone footing should be bedded in about $\frac{3}{4}$ inch of cement mortar. After this is set, the whole of the beam footings, top, sides, and ends, should be covered with at least 3 inches of cement and plastered with Portland cement mortar made in the proportion of 1 to 2.

62. In some cases, iron or steel rails are used for footings, and are cheaper than I beams. The footings are built up with from three to six layers of rails placed at right angles to each other. As each layer of rails is laid, concrete is filled between and around them, and when finished resembles a concrete pier.

Fig. 19 shows a footing and pier built in this manner. At *a* is shown the steel or iron rails with concrete between them; *b* is the base stone supporting the brick pier *c*; while *e* is a

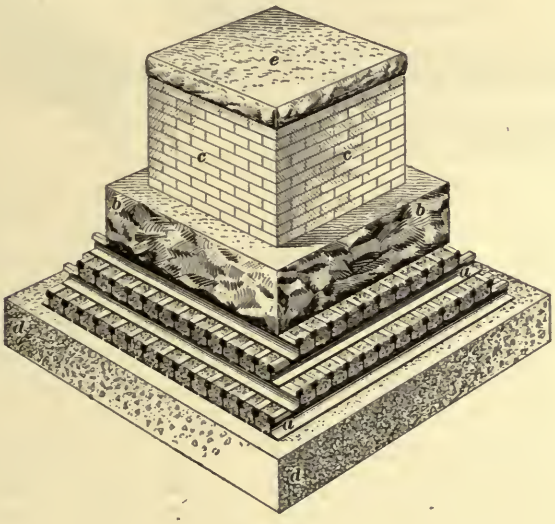


FIG. 19.

bond stone in the pier, and *d* is the concrete base. In this case, each layer of rails diminishes in length and number, until the area of the top layer does not greatly exceed the size of the pier base, the footing thus assuming a pyramidal form.

63. An example of the use of I beams is shown in Fig. 20. The 10-inch I beams *b* run transversely under the walls and are supported by the layer of concrete *a*, 12 inches thick. At *c* is shown the concrete on top of the

I beams; at *d*, the stone-footing courses of the foundation; and at *e*, the foundation wall.

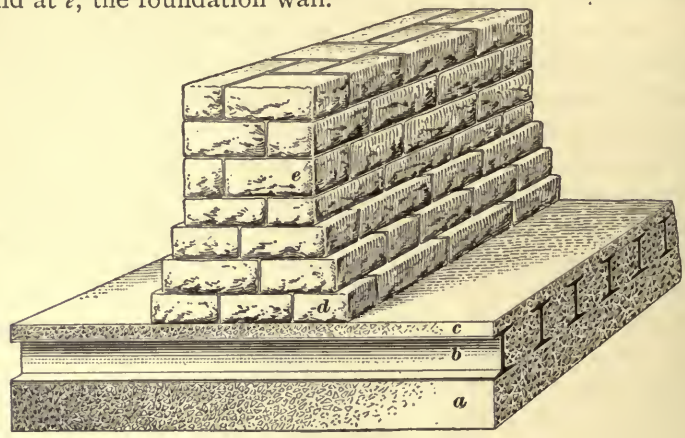


FIG. 20.

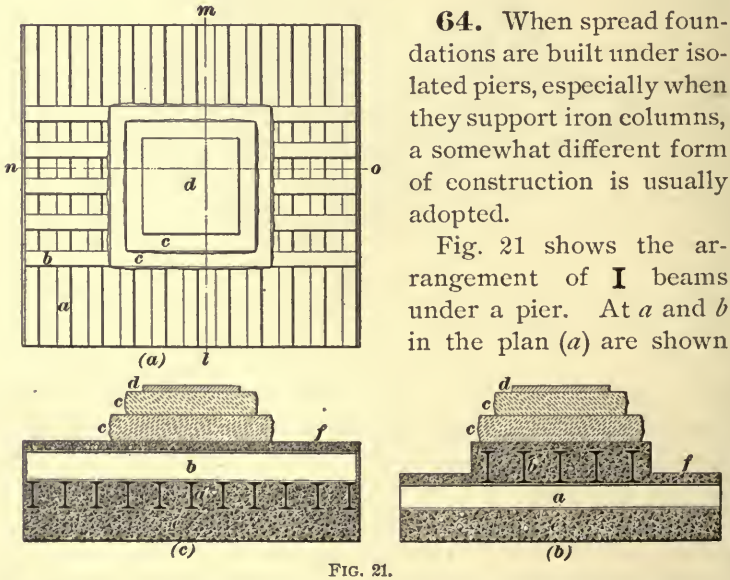


FIG. 21.

64. When spread foundations are built under isolated piers, especially when they support iron columns, a somewhat different form of construction is usually adopted.

Fig. 21 shows the arrangement of I beams under a pier. At *a* and *b* in the plan (*a*) are shown the I beams, and at *c* the foundation. The upper tier of beams *b* is laid transversely on the lower tier *a*, and the stone footings *c* carry the 3-inch iron plate *d* under the column.

At (*b*), Fig. 21, is shown a section taken on line *l–m* on the plan (*a*), where the concrete base, on which the lower tier of I beams rests, is shown at *e*, the lower tier of 10-inch I beams at *a*, and the concrete around the upper tier of beams at *f*; *b* is the upper tier of 10-inch I beams shown in section, and *c*, the stone-footing courses of brick pier under the iron plate *d*.

At (*c*), Fig. 21, is shown a view of the pier taken on line *n–o*, on the plan (*a*), which represents the lower tier of I beams in section, and the upper tier in elevation. The 12-inch course of concrete is shown at *e*; the lower tier of I beams at *a*; the upper tier of I beams at *b*; the concrete covering the beams at *f*; the base stones of the pier at *c*; and the iron plate under the iron column at *d*.

PROPORTIONING FOOTINGS.

65. It is very important that the foundations, whether continuous, as in a foundation wall, or isolated, as when divided into piers, should have the footing courses proportioned to the weight they will be required to carry, and to the bearing capacity of the soil.

The pressure on the soil from each square foot of the footings should be the same, where the soil is uniform, and at no place must the bearing power of the soil be exceeded. To secure the most satisfactory results, therefore, the footings must be proportioned to properly distribute the weight they are to carry over sufficient areas of ground, to secure uniform settlement in each case. If these conditions were always properly considered, there would be few cracks in the mason work, as such cracks are caused usually by unequal settlement. A uniform settlement even of an inch or more would in most buildings pass unnoticed.

66. In order to proportion the area of the footings, the weights coming on each pier, and the weight of, and loads carried by, all the walls should be computed, and entered in a memorandum book for reference. The ground should be examined, and by means of Table 1—the bearing power of different soils, see Art. **19**—the load per square foot which

it is deemed advisable the footings shall carry, may be determined. The load on the various footings divided by this unit load, will give, as results, the proper area of each, in square feet.

The pressure under a brick pier which supports a tier of columns may be assumed at 10 per cent. less than the calculations show, when the exterior support of the building is a brick wall; for the joints in the brickwork will close slightly under the weight and cause about 10 per cent. more settlement than will exist in the columns, each of which, being one piece, is practically jointless, and hence will settle less.

67. One of the objects in proportioning the footings is to provide for uniform settlement in all parts of the building, so that the floors may remain level, and that no cracks may occur in the walls. Therefore, the loads for which the footings are proportioned should be as near the actual conditions as possible, or, as stated in the Chicago building law, "Foundations shall be proportioned to the actual average loads they will have to carry in the completed and occupied building, and not to the theoretical or occasional loads."

Thus it will be seen that the dead load under the *walls* of a five-story building would be a considerable item, while the dead load under a tier of iron columns would be much less in proportion to the floor area supported; and as the dead load is always constant, and the live load may vary greatly, only the amount of live load that will *probably* be supported by the footings should be considered.

68. For warehouses, stores, etc., 50 per cent. of the live load that the floorbeams have to carry should be added to the dead load carried on the footings. For office buildings, hotels, dwelling houses, etc., the weight of the people occupying them need not enter into the calculations for proportions of footings, and only from 25 to 30 pounds per square foot of floor need be allowed for the weight of furniture, books, safes, etc. It has been proved by statistics that the average permanent loads do not exceed the above limits. For theaters, halls, etc., a larger allowance should be made for the

weight of people, but even a densely packed crowd of men will not weigh more than 100 pounds per square foot of floor.

69. Fig. 22 represents a building, the footings of which are to be proportioned. At (*a*) is shown the plan; at (*b*), the longitudinal section; and at (*c*), the transverse section of a

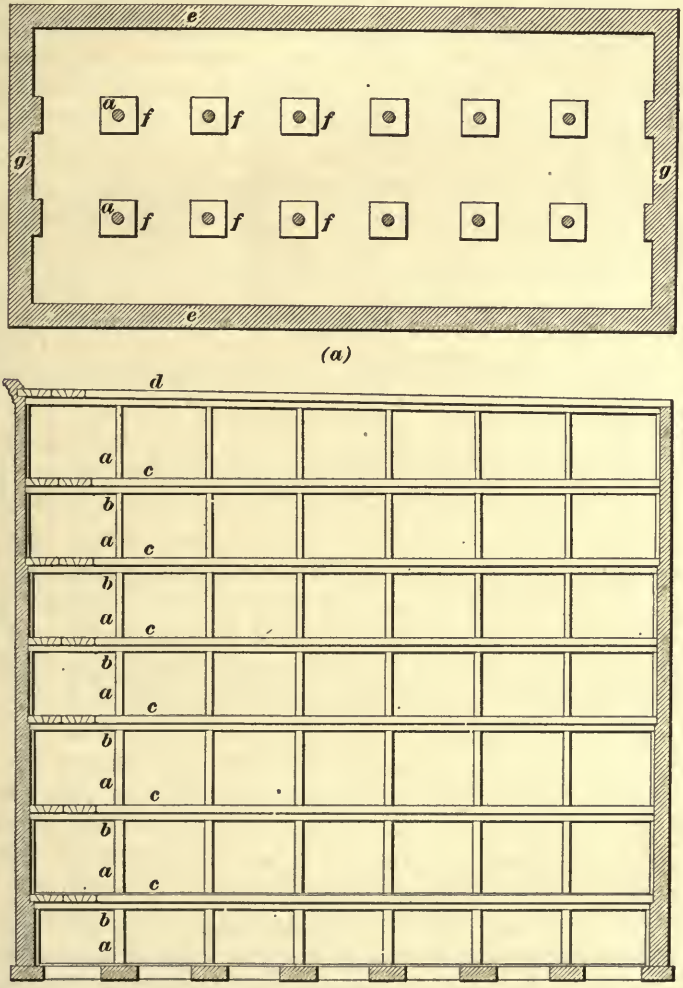
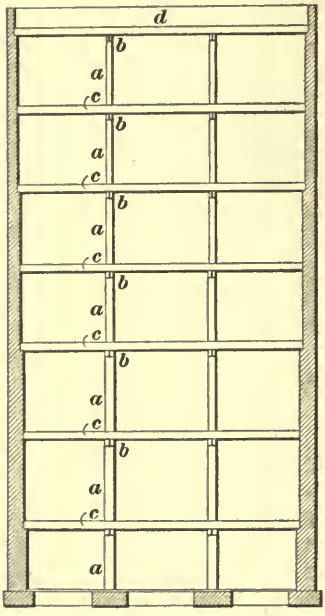


FIG 22.

six-story warehouse and its basement or cellar, supposed to be built on an ordinary sand and gravel soil. The building is 50 feet wide, with a double row of longitudinal columns *a* supporting iron girders *b*. What will be the dimensions of the footings under the walls and the columns?



(c)

FIG. 22.

The load on 1 lineal foot of the side walls will be about 140 cubic feet of brick and stonework, weighing about 17,160 pounds; 1 foot of wall has 8 square feet of each floor, shown at *c*, and an equal area of the roof *d* to support.

The floors are assumed to be constructed of iron beams filled in between with hollow terra-cotta tile, with cement filling on top. This floor will weigh, altogether, 75 pounds to the square foot of surface. The roof, shown at *d*, is also of fireproof construction, but with lighter iron beams, and weighs 60 pounds to the square foot. Thus the dead load from the six floors and the roof would amount to $8(6\times75+60) = 4{,}080$ pounds. The first, second, and third floor are supposed to carry 150 pounds to the square foot, and the fourth, fifth, and sixth floor, 100 pounds per square foot. The weight of snow on the roof is taken as 12 pounds per square foot. The total live load on the footings amounts to $8(3\times150+3\times100+12) = 6{,}096$ pounds per square foot. If the three loads—the wall, floors, and live load—are added, we have $17{,}160+4{,}080+6{,}096 = 27{,}336$ pounds on each lineal foot of the footing.

The soil will safely carry 6,000 pounds (3 tons) per square foot; dividing the load by 6,000, we obtain $4\frac{1}{2}$ feet as the required width of the footing, as shown at *e* on the plan (*a*), Fig. 22.

To obtain the load on the footings under the columns, we

must take the weight of the floors and the roof, together with the live load, the weight of the columns themselves being so little, in proportion to the other loads, that it need not be considered in the present example.

Supposing the columns to be spaced 14 feet apart longitudinally and 16 feet transversely, each column would support 224 square feet of floor; so we have a dead load on the footings under the columns amounting to $224(6\times75+60) = 114{,}240$ pounds, and a live load of $224(3\times150+3\times100+12) = 170{,}688$ pounds, a total of 284,928 pounds. Dividing by 6,000, gives us 47½ square feet as the area of the footing, or nearly 7 feet square. The footings of the front and rear walls may be figured similarly. These footings are shown at *g*, plan (*a*), Fig. 22.

70. A memorandum should be made of the calculations for the foregoing weights, etc., as follows:

DATA FOR FOOTINGS OF WAREHOUSE FOR THOMAS TUCKER, No. 1941 MAIN ST., TUCKERVILLE.

Under One Foot of Side Walls.		Under Columns.
Cu. ft. of brickwork 108 @ 120 =	12,960	
Cu. ft. of stonework 28 @ 150 =	4,200	
Total weight of wall.....	17,160 lb.	.....nothing
Floor area supported, 8 sq. ft.		16 × 14 = 224 sq. ft.
Weight of floor per sq. ft., 75 lb.		
Weight of roof per sq. ft., 60 lb.		
Total for six floors and roof		
510 lb. × 8 sq. ft. =	4,080	510 × 224 = 114,240
Live load per sq. ft.		
1st, 2d, and 3d floor, 150 lb.		
4th, 5th, and 6th floor, 100 lb.		
Weight of snow, 12 lb.		
Total live load..... 8 × 762 =	6,096	762 × 224 = 170,688
	27,336	284,928

Assumed bearing load of soil 6,000 lb. per square foot.
Width of footing course under walls 4 ft. 6 in. × 2 ft. thick.
Under columns 47½ sq. ft., 7 ft. × 7 ft. and 2 ft. thick.

PILING.

71. We now come to the subject of **piling**—an important branch of foundation work, which, though not masonry work in itself, is, as a supporting structure, yet considered as pertaining to masonry construction.

72. A pile may be considered as a column with a base more or less rigid, according to the nature of the soil into which it is driven. If a stick is driven down into damp sand, it will stand upright and support a load, even though it may not have reached firm bottom, the friction of the sand—or the pressure of its particles against the sides of the stick or pile—holding it in place. Thus when a pile is driven into the ground and its lower end rests on stiff clay or gravel, it is held in position by the friction against its sides.

It is usual to excavate to a point below where the heads of the piles are to be cut off, in order that they may be leveled up before the concrete is put in or the foundation begun.

73. Piles are usually driven by successive blows of a heavy block of wood or iron, falling from a height. This block weighs from 1,200 to 2,000 pounds, and is called a *hammer*, *monkey*, or *ram*. It is raised by means of a rope or chain that passes over a pulley fixed on top of an upright frame, and falls between parallel guides directly upon the head of the pile that is placed under it. The chain or rope is wound over a drum, which is driven by a small engine. After the hammer or ram is drawn up to the required height on the frame, it is released, and falls on the head of the pile, forcing it into the ground.

When the weight of the hammer and the height from which it falls are known, the distance a pile sinks at the last blow determines somewhat the load it will carry. The pile should be driven until it sinks not more than from $\frac{1}{4}$ inch to 1 inch at the last blow of the hammer, depending upon the character of the material into which it is driven.

74. Piles are generally round, and from 9 to 18 inches in diameter at the head, and should be straight, and clear

from bark and projecting limbs; but where piles are exposed to the rise and fall of tides, it is considered best to drive them with the bark on, since they are then not so easily affected by the action of sea-water, and are not likely to be attacked by the *teredo navalis* and other boring sea worms.

Oak, spruce, hard pine, cypress, and elm are the principal woods used for piling. Oak has the advantage of being hard and tough, and stands hammering well, but cannot be obtained in as large, straight, or long pieces as spruce, hard pine, or cypress. The long-leaf pine is hard and tough and can readily be obtained in good-sized logs of lengths up to 90 or 100 feet, and from 12 to 18 inches diameter at the butt, and from 5 to 12 inches thick at the lower end.

75. Piles are prepared for driving by cutting or sawing the large end square, bringing the small end to a blunt point with an ax, the length of bevel being from 1½ to 2 feet.

In very soft and silty material, there is no necessity of pointing the pile, and in fact it can be driven in better line if left blunt. A pointed pile on striking a root, or any obstruction of the kind, will invariably glance off and thus be thrown out of line; the blunt pile, on the contrary, will cut or break through the obstruction.

The large end of the pile should be cut or chamfered for a few inches from the end, so that a wrought-iron ring, 1 inch in thickness and 3 inches wide, will fit over the end of the pile tightly when struck one or two light taps by the hammer or ram. Sometimes a ring from 1 to 1½ inches less diameter than the pile is simply placed on the top of the pile, and driven into it by light blows. This, however, is not as desirable as the former method, as the ring is apt to split long pieces from the sides of the piles, and not usually being put on until the pile is more or less battered on the end, is likely to be carelessly placed, and not concentric with the head of the pile. The rings are used in pile driving in order to lessen the tendency of the pile to split or *broom*. Brooming is a term given to the splintering of the fibers on the end of the piles, due to the repeated blows of the ram.

76. Calculations for Piles.—The efficient bearing power of piles in different soils is very indefinite. A pile may go down through a stiff clay or gravel for some distance, sinking very little at each blow of the hammer, and may then penetrate a soft stratum, so that the pile will sometimes sink nearly as much at the last blow as at the first. In this case, the friction on the sides of the pile keeps it in place. But this friction is so great that even in marshy ground the ultimate bearing capacity of a pile 30 feet long is given as from 13,000 to 20,000 pounds, or from 6½ to 10 tons. In alluvial soil, or moderately soft clay, the bearing capacity is from 20,000 to 40,000 pounds, or 10 to 20 tons; and in stiff clay, or compact sand, from 40,000 to 100,000 pounds, or 20 to 50 tons.

77. Having the weight of the hammer, the height it falls, and the penetration of the pile at the last blow of the hammer, the following rule may be used for determining the load a pile will carry:

Multiply the weight of the ram in pounds, by the height it falls in inches, and divide the product by eight times the set or penetration at the last blow of the hammer.

The formula being:

$$P = \frac{Wh}{8\,a},$$

in which h = fall in inches;
W = weight of hammer in pounds;
a = penetration at last blow in inches;
P = safe load in pounds.

For example, suppose the weight of hammer to be 1,500 pounds; height of fall, 15 feet, or 180 inches; penetration of pile at last blow, 1 inch. Then $P = \frac{180 \times 1{,}500}{8 \times 1} = 33{,}750$ pounds, or nearly 17 tons, the load the pile will carry.

78. In all calculations of the bearing power of piles, a large safety factor is necessary, owing to the many uncertainties connected with the subject. The New York building laws require that a pile shall not be less than 5 inches in

diameter at the smallest end, and that when walls, piers, or posts rest on them, they shall be spaced not more than 30 inches from centers, and shall not carry more than 20 tons to each pile.

79. Shoeing Piles.—When piles are driven through soft material to rock or hard gravel, the force of the blows of the hammer has a tendency to split the piles, after rock or hard gravel has been reached, thus greatly impairing their bearing capacity; to prevent this, piles are often protected at the end with wrought or cast iron shoes. Fig. 23 illustrates three different methods of shoeing the ends of piles. At (*a*) is shown a $2'' \times 2\frac{1}{2}''$ wrought-iron strap *a* bolted through the pile *b*, forming a shoe, which is the same on both sides of the pile. At (*b*) is shown a cast-iron conical shoe fitted over the end of the pile *b*; the head of the shoe *c* protects the end of the pile, and the straps *a*, one on each side, hold the shoe in place. One of the best forms of cast-iron shoe is shown at (*c*), Fig. 23. In this case, the pile has a blunt end from 4 to 6 inches in diameter shown at *b*. The shoe has a solid conical point *c*, the top of its base being about the same diameter as the end of the pile; the straps then extend up on the sides of the pile, and are bolted or spiked to it, as shown. The straps and bolts hold the shoe in place, while the plate end of the pile receives the effect of the blow. A shoe of this kind, will, to a great extent, prevent the end of the pile from brooming.

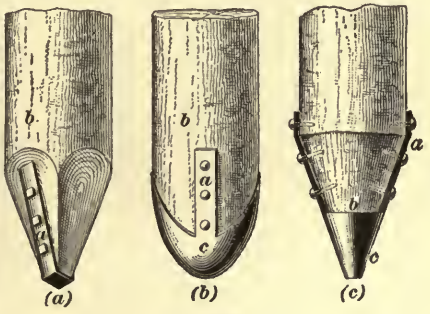


FIG. 23.

80. Protection of Piles.—When timber foundations have to be constructed, and the piles are exposed to sea-water, they are likely to be attacked by various wood-boring worms that will penetrate the piles and destroy ordinary

timber in from three to five years; but they do not often bore through the bark of piles, which seems to kill them before they can penetrate it.

To prevent the attack of these destroyers, the piles are often treated with creosote, or the heavy oil of tar. The sap and moisture are exhausted from the wood by creating a partial vacuum in an air-tight vessel or tank, in which the piles have been placed, and then forcing the creosote into the pores of the timber under a heavy pressure. By this means, the depredations of the *teredo navalis*, or sea worms, are almost completely checked.

81. Iron screw piles are often used for building piers and lighthouse foundations. These piles vary from 6 to 16 inches in diameter, and have a screw disk at one end, similar to one turn of a wood auger. They are screwed into the soil, sand, soft rock, coral reef, etc.

82. Sand piles are sometimes used in place of timber piles, especially where the soil is of a soft alluvial clay. The method usually adopted is to drive a pile from 10 to 14 inches in diameter into the ground 6 to 8 feet, and then pull it out; or this hole may be bored by means of a large screw auger. The holes thus formed are filled with damp sand well rammed down. This is done at intervals of 2 or 3 feet all around the walls of the structure to be supported. Owing to the great mobility of the sand grains, they press equally in all directions at any given depth, and hence transmit the pressure to the sides of the hole as well as to the bottom.

83. Timber Footings on Piles.—For footing courses on pile foundations several methods are practised. Fig. 24 shows a timber footing course, or capping, laid below the water level to prevent rotting. The piles *a* are cut off to an even height, and on these the heavy timbers shown at *b* are spiked longitudinally, and on top of the longitudinal timbers, the timbers *c* are laid transversely, and are secured to the first course on the piles. By this method the load is distributed evenly over the top of the piles.

84. Stone Footings on Piles.—Fig. 25 illustrates footings made of large-sized building stone with level beds. At *a* is shown the piles and at *b* the building-stone footings. These stones must in every case rest directly on the piles. Great care must also be taken that one pile comes under

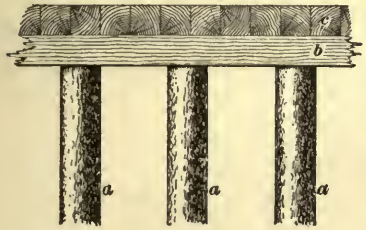


FIG. 24.

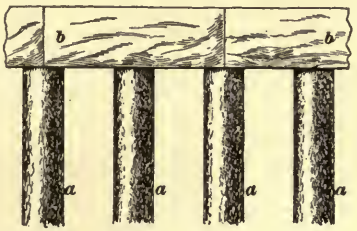


FIG. 25.

each corner of the stone, to keep it from tipping, and that the stone has a full bearing on each pile head. To insure this, the piles must be sawed off perfectly level and all the same height, as no pieces of wood or small bits of stone should be placed under the stones to give them bearing on the piles. Wooden chips crush under a load, and pieces of stone are likely to be broken or dislodged, leaving the block in a state of dangerous instability.

85. In many cases concrete filling is used between the piles, as shown in Fig. 26. After the piles are cut off at the water level, which is shown at *a e*, the earth is excavated to

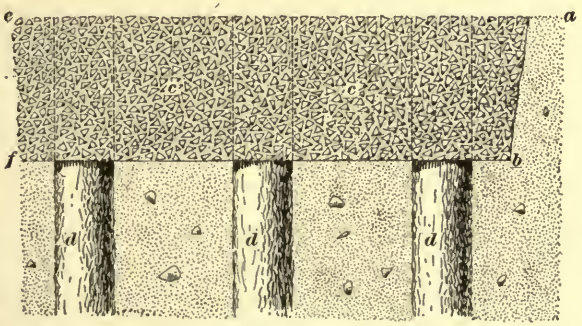


FIG. 26.

b f, usually about 2 feet, and the space thus obtained is filled in with the concrete *c*, well rammed around the sides of the piles *d*, and leveled off at the top to carry the foundation walls. This method is best adapted to situations where the soil is constantly wet, as then the piles will not become dry and rot.

In some instances the piles are planked over with 3-inch planking, laid transversely on top of the concrete, and on this the foundation walls are built.

86. Cluster Piles With Brick Arches.—Piles are sometimes driven in groups, and the building is carried on arches sprung from one group or cluster to another. Fig. 27 shows one form of this method of construction which has been successfully used on alluvial soil.

The piles shown at *a* are driven in groups of nine. They average 20 feet in length and are driven until they sink

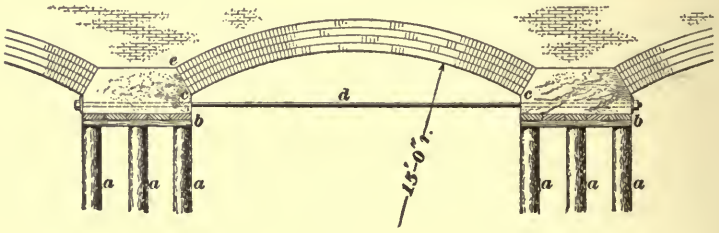


FIG. 27.

about 1 inch at the last blow of a hammer weighing 1,200 pounds. On the piling, 3″×12″ plank are laid transversely and longitudinally, spiked to the top of the piling, as shown at *b*, *b*. The stone skewbacks *c* are placed on this planking, and tied together with a 1¾-inch tie-rod *d*, upset on one end and secured by a nut and washer on the other. The brick segmental arch *e* is then sprung between the skewbacks. This arch has a radius of 15 feet, and is laid up in four courses, or rowlocks, of brick. The brickwork is 24 inches thick up to the level of the water-table of the building.

87. Terms Used in Pile Driving.—The technical terms used in pile driving are descriptive of the form or position of the piles, or the manner of their driving.

A **screw pile** has an auger at the lower end, and is sunk by a rotary motion, aided by downward pressure.

A **close pile** is one set close to another when the pile already driven shows signs of weakness.

A **false pile,** or **follower,** is an additional length added to a pile for deeper driving. Fig. 28 shows the manner of connecting the first pile driven and the follower; *a* is the first pile, *b* is the follower, and *c* is a dowel to preserve the alinement of the two piles. At *d*, *d* are shown wrought-iron straps, made usually of $2'' \times \frac{1}{2}'' \times 20''$ iron, to bind the two piles together.

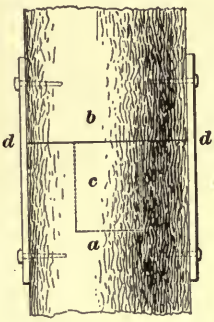


FIG. 28.

A **gauge pile** is a preliminary pile driven to mark the desired course.

A **filling pile** is one put in between gauge piles.

A **guide pile** is one driven to mark the limit of the field of operation.

A **sheet pile** is a flat timber driven in the ground, as described in Art. **25.**

A **wale** is a horizontal string piece to bind the piles together.

Pile hoops are bands around the tops to prevent splitting.

Test piles are the first piles driven to test the bottom, and should not be less than 6 inches in diameter.

CRIBS FOR CAISSONS.

88. Formerly, *caissons* were used exclusively for the foundations of bridge piers, but the advent of steel skeleton construction, and consequent erection of very lofty buildings, have caused caissons to be used for building foundations.

89. A **caisson** is a chamber of iron or wood that is used in the construction of deep foundations.

There are two different methods of reaching the required foundation.

First, when the desired depth is reached by excavating the material from the interior of a large timber or iron box, or cylinder, strongly constructed for the purpose, and then forcing the structure to sink against the exterior friction on its sides, by sufficient weights or loads placed in the caisson, until the required depth is reached. Structures of this kind are called *open caissons* or *open cribs.*

The second method is used when the foundations are to be carried to a great depth in very soft material or in water. The lower part of the caisson is then formed into an air chamber resting on the soil at the bottom. Air is pumped into this at a pressure corresponding to the depth below the surface, and the excavation is carried on by men working at the bottom, as in a large diving bell. Such a structure is called a *pneumatic caisson.*

After the crib or caisson is sunk to the proper level, either to rock or compact gravel, the inside space is filled with concrete; on this the piers or foundations are built, if the open caisson is used; and on top of the caisson, if the pneumatic method is used.

90. The work of sinking the cribs or caissons, is outside of the architect's province, and is usually entrusted to some firm of engineering contractors who make a specialty of work of this description, and who leave everything in readiness to construct the foundation walls or piers.

INVERTED ARCHES.

91. When a front or other wall is composed of isolated piers, it is well to combine all their footings into one, and to step the piers down, as shown in Fig. 29, in which *a* shows the concrete footing course, *b*, the stepped-up foundations of the piers, and *c*, the piers resting on the footings.

92. When there is not sufficient depth for this purpose, use is sometimes made of **inverted arches**; these are to be avoided unless the foundation wall is from necessity very

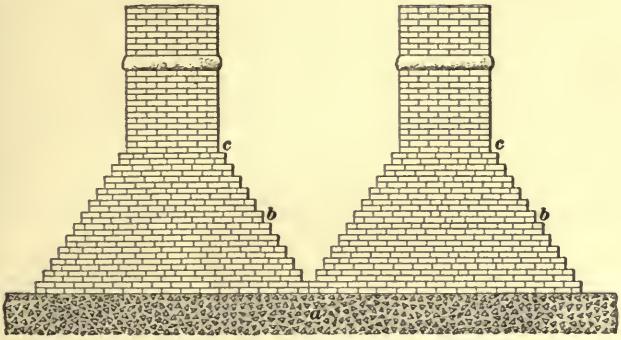


FIG. 29.

shallow, as great care is required to lay them properly, the slightest settlement in them having a disastrous effect upon the piers.

The end arch of the building must have sufficient pier or other support; otherwise it may throw the pier out, as shown by the dotted lines at *a*, *a* in Fig. 30.

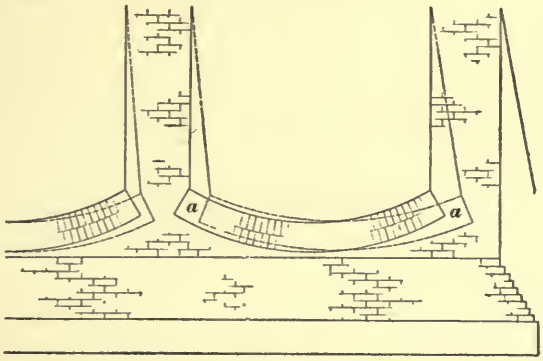


FIG. 30.

This difficulty is overcome by the use of an iron rod, with iron plates and nuts, as shown in Figs. 31 and 32, thus securing the skewbacks in place.

93. The New York building law, in referring to inverted arches, provides as follows:

"If in place of a continuous wall, isolated piers are to be built to support the superstructure (where the nature of the ground and the character of the building make it necessary), inverted arches shall be turned between the piers, at least 12 inches thick, of the full width of the piers and resting upon a continuous bed of concrete of proper area, and at least 18 inches in thickness; or two footing courses of large stone may be used, the bottom course to be laid edge to edge and the top course laid end to end; or one course of concrete and one course of stone.

"The stones shall not be less than 10 inches thick in each course; the concrete shall not be less than 18 inches thick; the area of the lower course shall be equal to the area of the base course that would be required under a continuous wall, and the outside piers shall be secured to the second piers with suitable iron rods and plates."

94. Fig. 31 (*a*) represents two piers connected by a brick and concrete inverted arch, each pier being 3 feet square.

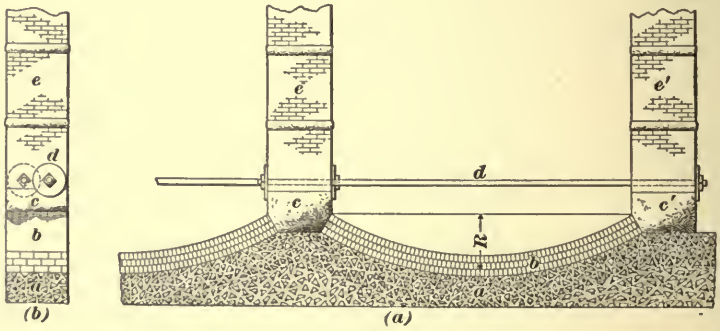


FIG. 31.

At *a* is shown the 18 inches of concrete under the 12 inches of brickwork *b*. At *c*, *c'* are shown the stone skewbacks from which the brick arches spring, and *d* is the 2-inch iron rod tying the end pier *e'* to the second pier *e*, and thus preventing the thrusting out of the end pier. At (*b*) is shown the inverted arch in section.

Fig. 32 shows an inverted arch built of stone 24 inches thick. At (*a*) is shown the stone arch *a*, maintained in position by the iron tie-rod *b*, and at *c*, the brick foundation

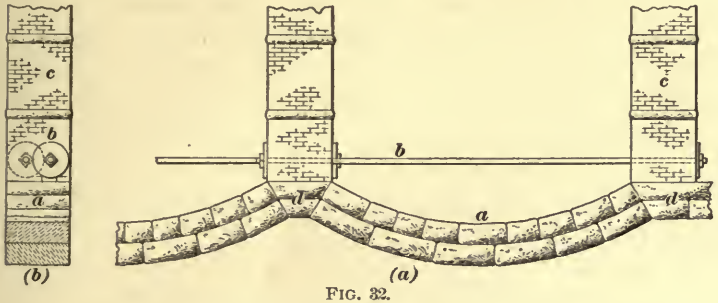


FIG. 32.

piers are shown upon the skewbacks *d*. At (*b*) is shown a section of the arch *a*, an end view of the tie-rod *b*, and elevation of the pier *c*.

95. The best form of inverted arch is the three-centered or elliptical, (as shown in Fig. 33); next, the pointed; third, the circular; and lastly, the segmental arch.

Fig. 33 represents the method of getting the lines for the centering in an elliptical arch. Divide the space shown on

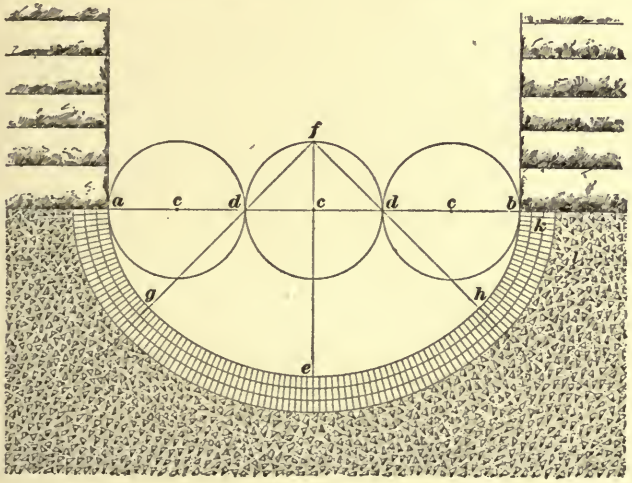


FIG. 33.

the line from *a* to *b* into three equal parts, then draw the three circles *c*, *c*, *c* so that the circumferences of these circles will be tangent at *d*, *d*. Then carry the perpendicular line *e–f* through the center of the middle circle; the point *f* where it intersects the circumference of the circle, gives the center of the arch from *g* to *h*. From *f* draw lines through *d*, *d* to *g* and *h*. The intersection of these lines at *d*, *d* gives the centers of the arch from *g* to *a* and from *h* to *b*. At *k* is shown the 12 inches of brick in the arch, and at *l* the concrete under it. This form of arch is used frequently in the construction of sewers.

FOUNDATION WALLS.

GENERAL CONSIDERATIONS.

96. The **foundation walls** above the footing courses are usually of stone or brick. The method of building brick foundations is the same as for all brick walls, therefore it will not be described here, but taken up under "Brickwork."

THICKNESS OF WALLS.

97. A very good rule to fix the thickness of stone foundation walls is, that they shall be at least 8 inches thicker than the wall next above them, for a depth of 12 feet below grade or curb level; and for every additional 10 feet or part thereof in depth, they should be increased 4 inches in thickness. Thus, if the first-story walls are 12 inches thick, the stone foundation walls would have to be 20 inches thick for 12 feet in depth, and 24 inches thick if the depth is increased beyond 12 feet. When of stone, the wall should not be less than 16 inches thick, as a thinner wall than this does not bond well, only small stones can be used, and it cannot be carried to any height.

The thickness of foundation walls in all the large cities is controlled by the building laws. Where there are no existing laws, Table 2 will serve as a guide:

TABLE 2.

THICKNESS OF FOUNDATION WALLS.

Height of Building.	Dwellings, Hotels, etc.		Warehouses.	
	Brick. Inches.	Stone. Inches.	Brick. Inches.	Stone. Inches.
Two stories.....	12 or 16	20	16	20
Three stories.....	16	20	20	24
Four stories.....	20	24	24	28
Five stories.....	24	28	24	28
Six stories.....	24	28	28	32

STONE RUBBLE FOUNDATION WALLS.

98. Stone foundation walls below ground, when concealed from outside view, are usually constructed of rough rubble, as shown in Fig. 34. This represents an elevation

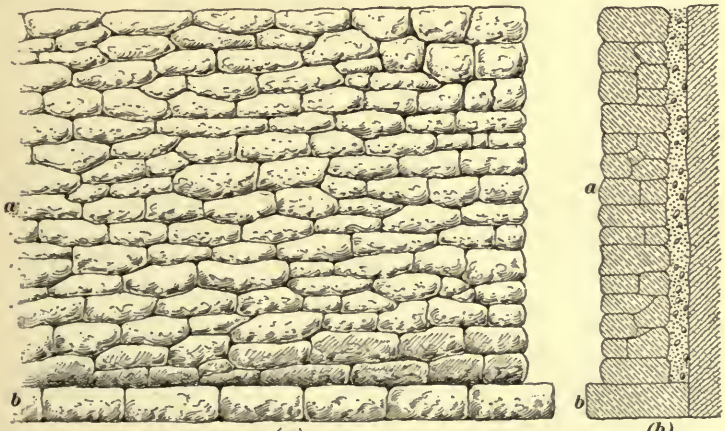


FIG. 34.

(*a*) and section (*b*) of a 20-inch rubble stone wall, shown at *a*, *a*, 10 feet high, with footing stones *b*, 8 inches thick, and 2 feet 8 inches wide.

99. Stone foundation walls should be bonded together, as shown in Fig. 35, where *a* shows the bond stone, or header, and *b* the stone foundation wall. All stone walls, 24 inches or less in thickness, should have at least one header extending through the wall, every 3 feet in height, and in every 4 feet of length. If the stone wall is over 24 feet in length, there should be at least one header for every 6 superficial feet of wall space, running into the wall at least 2 feet. The headers should not be less than 18 inches in width and 8 inches in thickness, and should be good, flat stone. These headers serve to bind the stones of the walls together, and keep the foundation from splitting apart crosswise when weight is placed upon it.

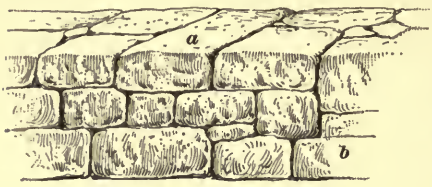


FIG. 35.

100. Fig. 36, at *a*, *a*, shows vertical joints coming one above another through three or four successive outside courses. This should never be allowed, but the joints of the stonework should be broken, as shown in Fig. 34.

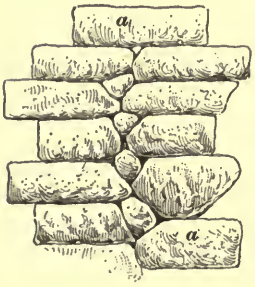


FIG. 36.

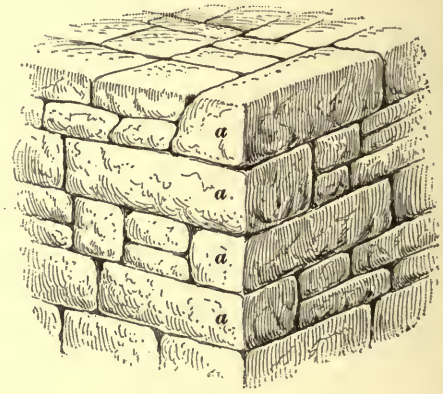


FIG. 37.

Where a long vertical joint occurs, the weight of the wall above may cause the wall to settle more on one side of the joint than on the other, and produce serious rupture.

101. All wall angles should be well tied by long stones laid alternately in the wall, as shown at *a*, Fig. 37, the long angle stones tying the wall at that point. By using these long stones, the weight on the corners of the wall is more equally distributed, and the wall can be kept plumb and true.

102. Foundation stone should always be laid on their natural or quarry beds. The tendency to splitting or cleavage in a stone is *with* the grain or bed; so when the stone is laid *on* the original bed, the weight of the material placed above it comes *against* the grain of the stone. No stone should have more face than bed, and one side, at least, of each stone should be reasonably flat. Every stone laid should be well bedded in mortar.

103. The usual practice with masons in rough walling is, after setting the larger stones, to fill the interstices with spalls or chips of stone, or even pebbles, more or less carefully fitted, and put in dry; then to dash in mortar, trusting it will work its way into the crevices. It does so to some extent, but the method is not a good one. A good, conscientious workman will place no stone, even the smallest chip, except in a bed of mortar prepared to receive it, rubbing it well in, and settling it with blows of the trowel and hammer; again driving smaller fragments into the mortar, which is squeezed up around it; so that all the stones have a layer of mortar between them.

A good plan is also to grout the walls with mortar, made so thin that it will flow into the spaces, and interstices, between the stone.

104. For good work, it is necessary that the outside of the wall (even when concealed by the excavated bank) should be carried up with a good face, as shown in Figs. 34 and 37, and the joints well filled with either cement, or lime-and-cement mortar. If this is properly done, any moisture that runs out from the bank or descends from above, so as to flow down over the outer face of the wall, will drip off, instead of running into the joints.

105. The space between the outside of the foundation and the bank of the excavation should be filled in with gravel or sand (preferably the former), well packed down. Thus in Fig. 38, *a* shows the space between the foundation wall and the bank, while *b* is the stone wall. This method makes the cellar drier and warmer, and keeps much of the moisture away from the foundation walls.

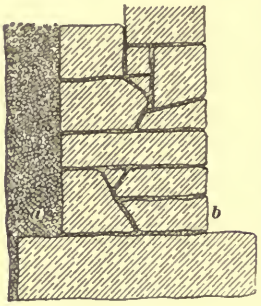


FIG. 38.

FOUNDATION WALLS PARTLY ON ROCK.

106. A very faulty construction sometimes met with is that in which a portion of a ledge of rock projects into the foundation wall, and the foundation is built partly on the rock and partly on the footing course. This is shown in Fig. 39, *a* being the footing course; *b*, the rock projection into the foundation wall; *c*, the thin wall in front of the rock to bring the foundation to the thickness figured on the plans; and *d*, the wall of the building carried up to its full height and thickness, and resting partly on the thin wall *c*, and partly on the ledge of rock *b*.

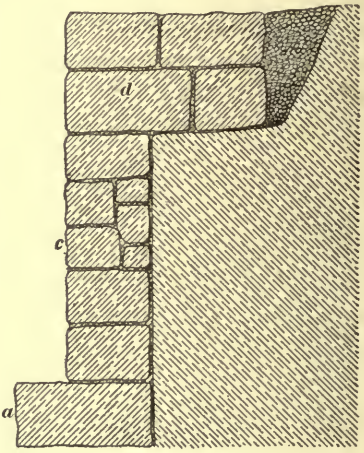


FIG. 39.

In a wall so built, the water will find its way either through the imperceptible seams of the ledge of rock *b*, or over its top into the body of the masonry, keeping it constantly damp. Besides, there is a serious risk that under the heavy weight of the upper wall, the thin lining built up against

the ledge—but in no way bonded to it—would separate from it and fall away, leaving the superincumbent masonry most insecurely supported. There is, besides, the certainty that the foundation wall, built partly on unyielding rock, and partly on softer soil, will settle unequally, and crack, perhaps injuring the masonry above, and, at least, opening an inlet for moisture.

The ledge should be cut away so as to leave ample space for the whole thickness of the foundation walls down to the footings, with sufficient space between the wall and the ledge of rock for packing gravel, as shown at *a*, Fig. 38. This will intercept the water and carry it away from the wall.

OPENINGS IN FOUNDATION WALLS.

107. When there are window or door openings in a foundation wall, the stones under the opening should be

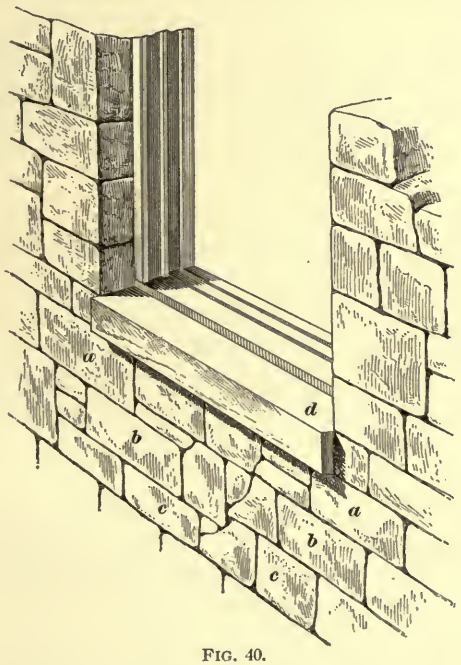


FIG. 40.

laid as shown at *a*, *b*, *c*, Fig. 40. This is done to spread the

weight of the wall under the door or window. If there should be a great amount of weight resting on the foundation walls, the window sills should not be built in the wall, but should be slip sills, as they are called, or sills that are just the width of the opening, as shown at *d*, Fig. 40. There will then be no danger of breakage by reason of uneven settlement of the wall; otherwise, if the wall settles more on one end of a built-in sill than on the other, the sill will probably crack.

AREA WALLS.

108. It is often found necessary to excavate areas outside the foundation walls of a building. These serve to light the building in some cases, and in others to give access to the basement. In order to keep the bank of earth from caving in, and to present a neat appearance on the inside, they require a surrounding wall. Stone walls, when the joints are wet, offer greater resistance to sliding on the bed than brick walls; hence, area walls are usually built of stone.

109. When excavations are made for area walls, the bank ought to be disturbed as little as possible, and when the soil is thrown back behind the wall, it should not be dumped carelessly, but deposited in layers, and well tamped. No filling should be done until the mortar in the wall has had time to harden; or if the filling has to be done at once, the wall should be well braced.

110. Areas are usually built in the same manner as stone or brick foundation walls; that is, they are laid up in cement mortar, and have a thickness of 20 inches for a stone wall to a depth of 7 feet, and 16 inches for a brick wall to the same depth.

When an area wall exceeds 7 feet in depth, there should be a batter on the area side, as shown in Fig. 41, and it

should be increased in thickness at the bottom, so that the average thickness will be one-fourth the height, unless the wall is braced by arches, buttresses, or cross-walls.

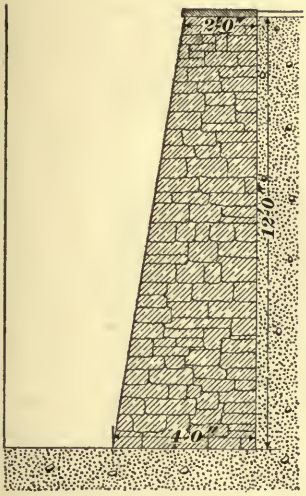


FIG. 41.

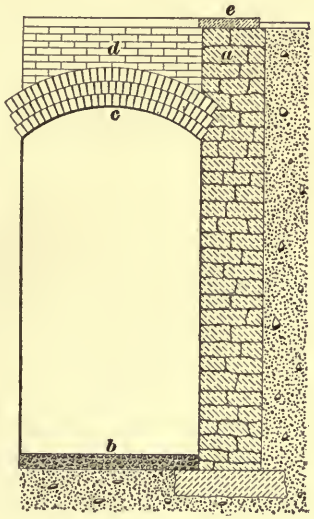


FIG. 42.

When an area wall is 10 feet long, bracing arches can usually be thrown from one wall to another, as shown in Fig. 42. Here *a* shows the area wall; *b*, the concrete bottom of the area itself; *c*, the bracing arch, shown in this case as a segmental arch made of three courses of brick; *d*, the brick filling on top of the arch; and *e*, the area coping.

WINDOW AND ENTRANCE AREAS.

111. These are not strictly a part of the foundations, but are usually made part of the same contract, and built at the same time and in the same manner as the foundation walls.

All window areas should be of good size so as to obstruct the light as little as possible. When small cellar windows

are not sunk more than 2 feet below the grade line, a small semicircular area, as shown in Fig. 43, will give the most satisfaction for a small cost. At *a* is shown the foundation wall of the building; at *b*, the window and window opening through the wall; at *c*, the area; and at *d*, the semicircular area wall, in this case an 8-inch brick wall. When the area

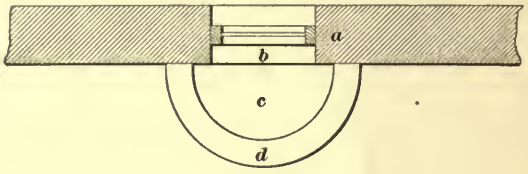


FIG. 43.

is 3 or 4 feet deep and the same in length and width, the brick wall should be at least 12 inches thick, and if a stone wall is built, it should be 18 inches thick.

The coping of areas should be stone flagging laid in cement. This flagging is usually bluestone, granite, or blue Vermont marble, as freestones and all other porous stones are not suitable for area or wall copings. The flagging is generally from 2 to 2½ inches thick, and projects 1 inch over the face of the wall. If good coping stone is found too expensive, Portland cement mortar, made of equal parts of cement and sharp sand, laid on about 1 inch thick, may be used in place of the stone.

112. All areas should, if possible, be drained, in order to dispose of rain water and melted snow. To do this effectually, the bottom of the area should be made of cement mortar, laid in the proportion of 1 part cement to 1 part sand, or of stone flagging, or even of brick laid in cement, and should be carried about 6 inches below the window sill.

If the area is a large one, a small cesspool or sand trap, about 8 inches square, with 4-inch brick walls laid in cement mortar should be built, connected by a 3-inch drain pipe to the main drain. All open well holes and light shafts should have similar traps and drain pipes.

The arrangement for draining an outside area is shown in Fig. 44. At *a* is seen a cast-iron strainer, which sets over the cesspool a little below the pavement, to prevent rubbish, dead leaves, etc. being washed in the trap and clogging up the drain pipe; this strainer can be lifted out to clean out the cesspool when necessary. At *b*, the 3-inch drain pipe leaves the cesspool to connect with the main drain or sewer.

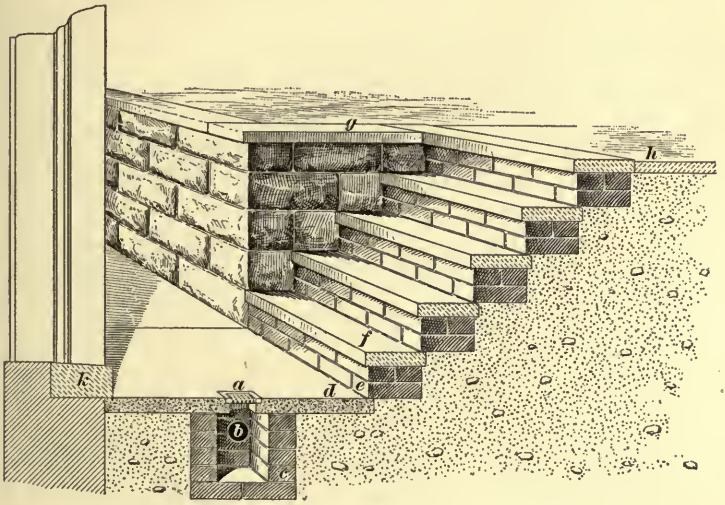


FIG. 44.

At *c* is the 8-inch brick cesspool; the stone, brick, or cement area pavement is shown at *d*; while at *e* are shown the brick risers of the area steps. At *f* are the stone treads; at *g*, the stone coping of the area walls; *h* is the pavement; and *k*, the stone sill of the door opening on to the area.

AREA STEPS.

113. All **area steps,** when practicable, should be of stone or a combination of stone and brick. Areas that are more than 6 feet deep, or where the soil is sandy, gravelly, or a wet clay, should be excavated under the steps, and

the steps themselves should be entirely surrounded by a wall.

The foundations for all outside stone steps, fence coping, etc. should be carried at least 2 feet below grade, and if built in localities likely to be affected by frost, they should be carried below the freezing line.

If the soil is hard and compact, or in localities where it is not subject to upheaval by frost, small flights of steps may be economically built by shaping the treads and risers in the earth, and laying two courses of brick in cement for the risers, and 2-inch stone flags for the treads, as shown in Fig. 44. Nothing but cement mortar should be used in setting the steps, which should be well pointed on completion, and the ends of all the stone treads built into the side of the earth walls.

114. Either solid stone blocks or 2 to 3 inch stone flags may be used in forming the treads and risers, the side wall in either case supporting the ends. If the steps are made of solid stone, the front of each block should rest on the back of the block below it, as shown at (*a*), Fig. 45. If the

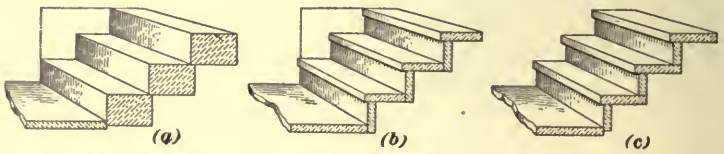


FIG. 45.

treads and risers are made of stone flagging, they are arranged as shown at (*b*) or (*c*), Fig. 45. The best arrangement is shown at (*b*). When the steps are more than 5 feet long, a bearing wall or iron string piece should be built under the middle of them. There should always be a pitch, from rear to front, of $\frac{1}{8}$ of an inch in the width of the tread, to secure the proper drainage.

Plank steps supported on plank string pieces are used in many localities; also iron steps with plank treads. The ground should be excavated, and the area walled up under them. When the plank treads decay or are worn out, it is

a matter of small expense to replace them. The steps should finish on a platform made of cement, flagging, or brick, ending at least 4 inches below the top of the entrance door sill.

VAULT WALLS AND VAULTS.

115. It is customary in all large cities to utilize the space under sidewalks for storage and other purposes. Indeed in many cases engines and boilers used for driving machinery or hoisting elevators are placed beneath the sidewalk. **Sidewalk vaults,** as such spaces are termed, necessitate a wall at the curb line to retain the roadway in place and to hold up the sidewalk.

116. The New York building law requires, "In buildings where the space under the sidewalk is utilized, a sufficient stone or brick wall shall be built to retain the roadway of the street, and the side end or party walls of such building shall extend under the sidewalk of sufficient thickness to such wall. The roofs of all vaults shall be of incombustible material. Openings in the roofs of vaults for the admission of coal or light, shall be covered with lens lights in iron frames, or with iron covers having a rough surface, and rabbeted flush with the sidewalk. Where areas are covered over, iron, or iron and glass combined, stone, or some other incombustible material shall be used, and sufficient strength in such covering shall be provided to insure safety to persons walking on the same, and to carry the loads which may be placed thereon. Open areas shall be properly protected with suitable railings."

117. A method of construction in use where partition walls can be placed under the sidewalk vaults is shown in Fig. 46. The partition walls *a* are placed about every 10 feet, and are usually 12 inches thick. The outer or street wall is shown at *b*. It is built in the form of an arch of hard brick laid in cement mortar. These arches are usually 16 inches or two bricks thick, and the "rise," or height of the arch above the springing line, is one-sixth of the span.

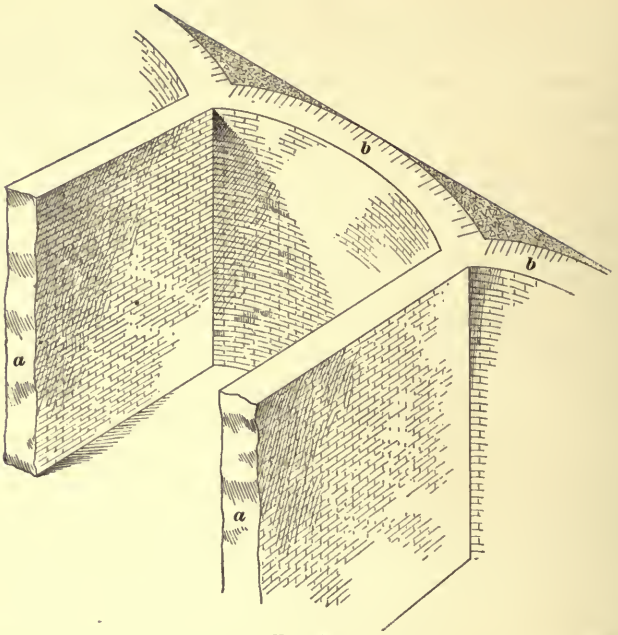


FIG. 46.

118. When it is desired to have the vault unobstructed by partitions, each sidewalk slab may be supported by an **I** beam column, as shown in Fig. 47. In this method of construction, the iron columns *a* support the outer ends of the

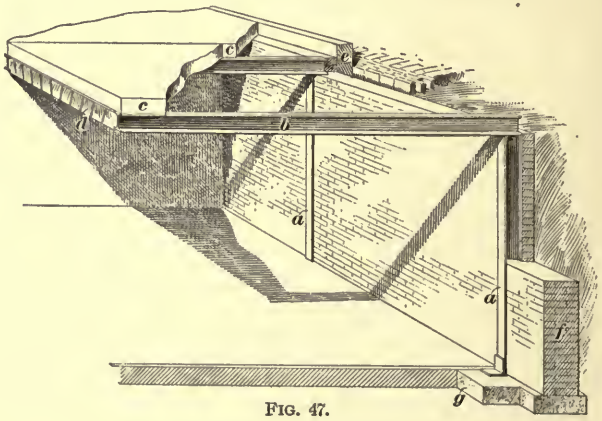


FIG. 47.

I beams *b*, which carry the stone flag or concrete pavement, shown at *c*. The space between the I beams is filled by the fireproof blocks *d*. The curb stone is shown at *e*; when

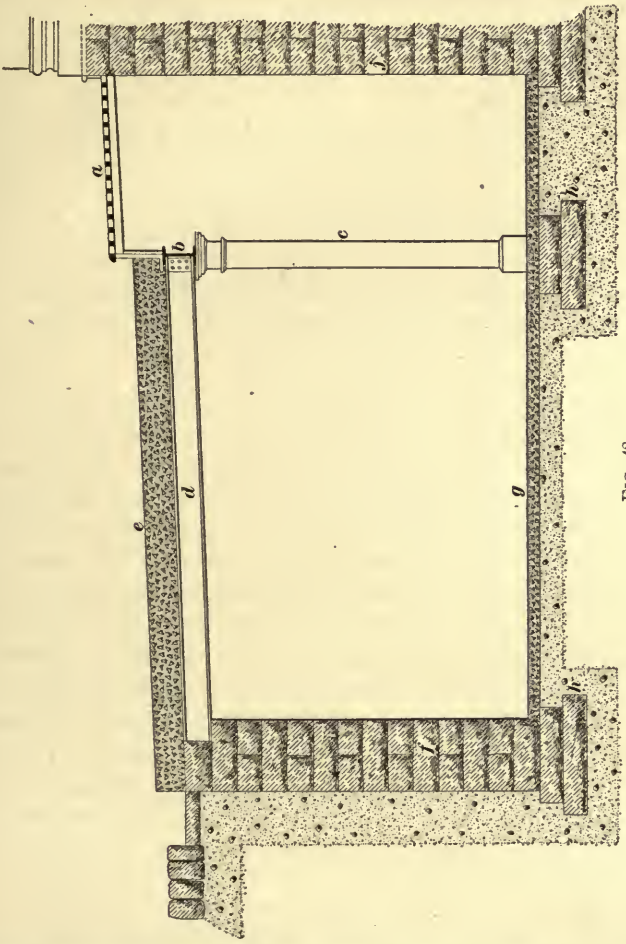


FIG. 48.

bluestone or granite flags are used, they are usually carried out to the gutter line and project over the curb stone, or, if sufficiently thick, the curb stone is omitted. The wall between the columns is indicated at *f*, and *g* is the concrete base on which the columns rest.

119. Another method of construction shown in Fig. 48, is used in large cities, where the vault requires light from above. At *a* is shown the area vault covered with thick glass in iron frames, known as patent or vault lights; *b* is the longitudinal I beam resting on the iron columns *c*, and bolted to the sidewalk girders *d*; *e* shows the flag or concrete sidewalk; *f*, the wall at the curb line carrying the ends of the sidewalk beams. This wall is shown in the illustration as built of stone, but brick is often used; both stone and brick should always be laid in cement mortar. At *g* is shown the floor of the vault, usually made of 3 inches of concrete, covered with 1 inch of Portland cement mortar, made in the proportion of 1 of cement to 1 of sand; *h* shows the footings under the sidewalk wall and under the iron column carrying the area I beam, and *j* shows the foundation wall of the building.

120. Sidewalk vaults are either arched over with brick or hollow tile; the top of the arch is leveled off with sand, cinders, or concrete, preferably the latter, and the sidewalk is laid on this; or a sidewalk made of large stone flags may form the roof of the vault. The best stone for this purpose is North River bluestone flag, though any compact limestone will answer the purpose. Granite is also used, but wears so smooth as to be objectionable in winter. The joints of the stone are closely fitted, and often rebated; then they are caulked with oakum, which is forced in, to within about 2 inches of the top, and the remaining space is filled with hot asphalt or asphaltic mastic. The joints will require cleaning out, and refilling, every few years, if they are to be kept water-tight.

If brick or terra-cotta arches are used, and a brick pavement is laid on them in sand, the top of the arch should be coated with hot asphalt.

121. Vaults are sometimes extended out beyond the curb line, under the street. This arrangement does not differ from that shown in Fig. 48, except that another line of columns and girders is placed under the curb line.

Sidewalk vaults are sometimes carried 25 feet below curb lines, and have two stories under the sidewalk, but the

construction does not differ materially from that already given. In nearly all the large cities, special permits are required for such kinds of vaults.

CALCULATION FOR SIZE OF STONE.

122. The size and thickness of stone flagging required for sidewalks, when the distance between supports is given, can be calculated by the following formula:

Let b = width of stone in inches;
d = thickness of stone in inches;
l = distance between bearings in inches;
A = constant from table;
W = breaking load at center of span;
W' = breaking load uniformly distributed over span.

Then,
$$W = \frac{A\,b\,d^2}{l};$$
$$W' = \frac{2\,A\,b\,d^2}{l}.$$

In words this formula may be expressed as follows:

Multiply together the width in inches, the square of the thickness expressed in inches, and the proper constant from the table, and divide by the span in inches; the quotient will be the breaking load at the center; and the quotient multiplied by 2 will be the breaking load if uniformly distributed. The allowable load should not exceed $\frac{1}{10}$ of the breaking load.

The following table gives the value of A in the above formula, in tons of 2,000 pounds, according to the different materials used.

Bluestone Flagging	.744
Quincy Granite	.624
Little Falls Freestone	.576
Belleville, N. J., Freestone	.480
Connecticut Freestone	.312
Dorchester Freestone	.264
Aubigny Freestone	.216
Caen Freestone	.144
Glass	1.000
Slate	1.200 to 1.700

For example, a block of Quincy granite 80 inches wide, and 6 inches thick, resting on supports 36 inches in the clear, would break under a load, resting midway between supports of $W = \frac{.624 \times 80 \times 6^2}{36} = 49.92$ tons; dividing this by 10, to get the safe weight, we have $49.92 \div 10 = 4.99$, or say 5 tons. When the load is equally distributed over the flagging, it will carry $2 \times 5 = 10$ tons.

PAVEMENTS AND SIDEWALKS.

123. Pavements being so nearly related to the masonry work of a building, and usually specified in a mason's contract, are discussed at this point.

124. Pavements may be made of thin slabs of stone, called flags, with a concrete base and Portland cement on top for a finish, or of very hard bricks known as paving brick.

In localities where large stone flagging is cheap and plentiful, it makes probably the most economical pavement, and is about as satisfactory as any, though a smooth and exceedingly durable pavement can be made with concrete and cement. But should it ever be necessary to cut through the pavement or change the grade, the cement and concrete must be destroyed, while stone flagging, on the contrary, can be taken up and relaid either in the same place or used elsewhere. It is also easier to repair a stone pavement than any other kind.

125. **Stone pavements** should be built of a kind of stone that will split with comparatively smooth and even surface, as when the surface of the stone requires dressing the pave will be more expensive than when concrete and cement or paving brick are used. Stone pavements for yards and the flagging of areas should be from $2\frac{1}{2}$ to 3 inches thick, with the edges trimmed smooth, so that the stone will be rectangular and the joints straight. The flags should be

laid on a 2-inch bed of sand, and for good work the edges should be bedded in cement, as shown at *b* in Fig. 49, where

FIG. 49.

a shows the stone flagging, *b* the cement joint, and *c* the sand bed. The cement should run 3 or 4 inches under the stone, and the joints in the pavement should be well filled with cement mortar, made of 1 part cement to 1 part sand.

126. Stone sidewalks are laid in much the same manner, but should consist of stones 5 feet long and 3 inches thick; or, if they are 8 feet long or more in length, they should be 5 or 6 inches thick. It is best to lay sidewalks in one course from curb to fence line, unless they are exceptionally wide.

In most of the Northern and Western states, the stones, if laid only on a bed of sand, will be affected by the frost, and become displaced and out of level in two or three years. Flagstones, therefore, especially on business streets, should have a solid support at each end. Fig. 50 shows the proper

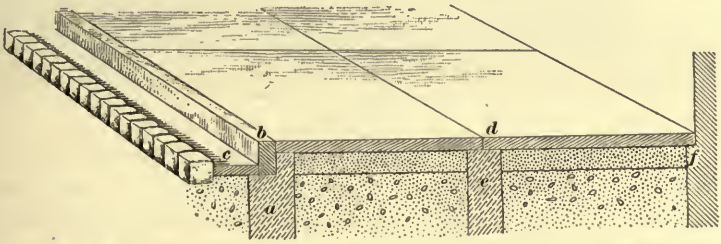


FIG. 50.

method of laying a pavement so that it will not be affected by frost. A 12-inch dwarf wall should be built at the curb line, as shown at *a*, and carried below the frost line. The curbstone *b* is from 4 to 6 inches thick, and rabbeted into the dwarf wall; *c* shows the gutter, and *d* the stone pave-

ment, supported at its center by a small wall *e*. If the sidewalk is laid in two courses, or if it extends to the building line, it may rest upon a break in the foundation wall *f*, as shown.

127. Cement sidewalks should be laid as follows: The ground should be leveled off about 10 inches below the finished grade of the walk, and well settled by ramming. A foundation 5 inches thick should then be laid, of either coarse gravel, stone chips, sand, or coal ashes, well tamped, or rolled with a heavy roller. The concrete should then be prepared in the proportion of 1 part of cement, 2 parts of sand, and 3 parts of gravel, mixed dry; then a sufficient quantity of water is added to make a stiff mortar. This concrete should be spread in a layer from 3 to 4 inches thick, and should be well tamped. Before the concrete has set, the top or finishing coat should be laid, and only as much concrete should be used as can be covered with cement on the same day, for if the concrete gets dry on top, the finishing coat will not adhere to it. The top coat should be prepared by mixing 1 part of the best Portland cement, and

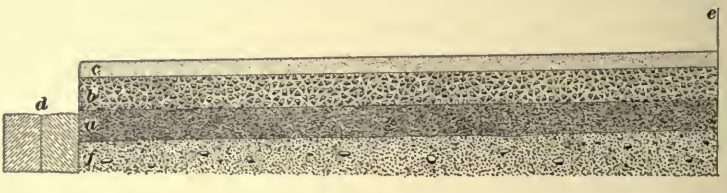


FIG. 51.

1 part of fine sand or 1 part clean, sharp, crushed granite or flint rock. The materials should be thoroughly mixed dry, and water then added to give the consistency of plastic mortar. It should be applied with a trowel, to the thickness of 1 inch, and carefully smoothed and leveled on top between straightedges laid as guides. Used in the above proportion, 1 barrel of Portland cement will cover about 30 square feet of pavement. Fig. 51 shows a section of a concrete pavement; *a* shows the ashes or spalls; *b*, the second coat of cement and gravel or stone; *c*, the finishing

coat of Portland cement; *d*, the street having; *e*, the building line; and *f*, the soil.

128. **Brick sidewalks** should be laid with good, hard, paving brick, sound and square, laid flat, herring-bone fashion, on a bed of sand from 4 to 6 inches thick. After the bricks are laid and graded (which should be about 1 inch to 10 feet, to drain the water to the gutter), the entire surface must be covered with sand, which must be swept over the bricks until the joints are thoroughly filled. If extra thickness of wearing surface is desired, the bricks may be set on edge, and covered with sand as above described.

RETAINING WALLS.

129. When a wall has to keep in place a filled-in backing of earth, rock, or gravel, it is called a **retaining wall,** because it retains the earth in its place, and resists its natural tendency to cave in. Foundation walls also act as retaining walls, with this difference, that they support a superstructure whose weight is usually found sufficient to overcome the thrust of the earth against the wall. A true retaining wall carries itself, and also must have strength enough to resist the pressure of the earth behind it. Area walls are, to a certain extent, retaining walls; but, as has been already shown, they are usually braced by arches or cross walls from the foundation wall, and hence do not require the same thickness as a retaining wall proper.

130. Nearly every writer on engineering subjects has some theory or formula for computing the best section and thickness of retaining walls. The best authorities admit, however, that so many conditions enter into the design of these walls—the nature of the soil, how far and to what extent the bank has been disturbed, the way the earth or other materials is filled in against the walls, etc.—that they can place but little confidence in theoretical

formulas, and prefer to be guided more by rules based on experience.

131. The cross-section generally used by engineers is shown in Fig. 52. The wall may be built plumb on the inside, as shown, or inclined against the bank. The latter

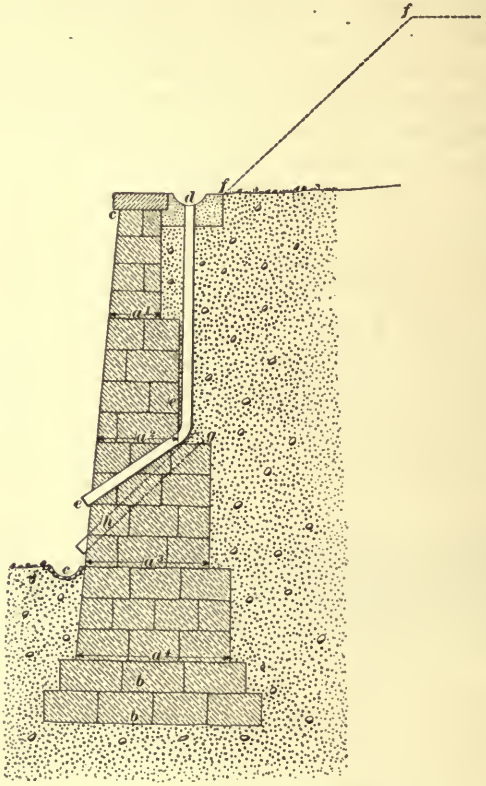


FIG. 52.

method is considered to be the better one, on account of giving more stability, but it is more difficult to build well, and as the beds of the stones must all be inclined, water running down the face of the wall is likely to penetrate the joints.

The best material for retaining walls, and the one generally used, is good hard split or block stone, having a level

bed, always laid in cement mortar, and carefully bonded, so that the stones will not slide on the bed joints from the pressure of earth behind them.

The wall should be not less than 12 inches thick on top, and the thickness above each step should be about one-third distance from the top. Thus, in Fig. 52, the wall at c is 12 inches thick, at a^1, above the step the distance from the top is 4 feet and the wall is 1 foot 4 inches (= 4 ft.÷3) thick; at a^2, the distance from the top is 8 feet and the wall is 2 feet 8 inches thick; at a^3, the distance from the top is 12 feet and the thickness of the wall is one-third of 12 feet, or 4 feet; while at the base a^4, the wall, being 15 feet high, is 5 feet thick. At b, b are shown the footings, each course 12 inches thick, and each projecting 6 inches beyond the course above.

The stability as well as the appearance of a retaining wall is increased by battering or sloping it outwards. This batter, as shown at c, c, is usually about 1 inch to the foot.

132. When the ground back of the wall slopes *towards* the wall, a cement gutter d should be formed behind the coping and connected with a drain pipe e, to carry off surface water that would otherwise run down behind the wall and affect its stability. Sometimes an open drain is placed at g, on the section connected with the gutter at the bottom of the wall as shown by the dotted lines h; where the backing of the wall is gravel, or a shelving clay bank with sand on top, this precaution is necessary. The form of drain used is shown at (b) in Fig. 5.

133. When the earth is terraced or banked up above the wall, as shown by the dotted line f–f, additional thickness is required. It is generally agreed that if the embankment is one-third the height of the wall, the wall should have a thickness equal to one-half the distance from the top. Therefore, the wall at a^2 would be 4 feet thick; at a^3, 6 feet thick; and at a^4, 7 feet thick. The stability of a retaining wall is increased by stepping the wall on the back, because the steps bond the wall into the material behind it, and the weight of the soil resting on the steps being added

to the weight of the wall, it is not so likely to slide out at the bottom. The footings should be carried well below the base of the wall to insure against heaving from frost or settling. It is also well to plaster the back of the wall and the top of the steps with cement, to a depth of 3 or 4 feet from the top of the wall.

DAMPNESS IN CELLAR WALLS.

134. A dry cellar is one of the most essential requisites of a healthy house. A moist or damp cellar acts as a reservoir of chilly and impure air, and the constant movement of air in the living and sleeping rooms created by the warmer atmosphere, causes currents of this damp cellar air to rise through the inhabited rooms and become a menace to the health of the occupants. When basements are used for storage, it is also very necessary to guard against dampness in the cellar walls.

135. There are several ways of preventing moisture from entering the walls, either by applications of cement or asphalt to the outside of the walls, or by means of drainage.

If only surface water has to be guarded against, cement or asphalt placed on the outside of the cellar wall is usually found sufficient. It is often specified that foundations shall be cemented on the outside, from the footing to the base-boards of a frame house, or to the stone water-table of a brick house. When it is not desired that the cement should show above ground, the cement is usually stopped from 4 to 6 inches below the grade line.

Asphalt applied to the outside of a wall when boiling hot, is generally considered to be the most lasting and durable of all coatings. Its color, however, does not harmonize with either brick or stone work, hence it is usually put on under the ground or on the inside of cellar walls. When asphalt is applied, it is necessary to have the wall built as carefully as possible, with the joints well pointed; and the wall must be thoroughly dry before the coating is applied. The wall should have at least two coats of asphalt, carried down to the bottom of the footings.

136. Some clay soils, though sufficiently solid to support the walls of dwelling houses, still retain moisture in wet seasons that is not carried away into the earth, but rises in the cellar, keeping it almost always damp. Fig. 53 shows a method of damp proofing a cellar bottom and walls which has proved successful. The cellar is first prepared by laying 3 or 4 inches of sand, shown at *a*, which is to be rolled down firm and even. Around the cellar walls, shallow gutters *b* are made in the sand, and a coating of cement *c*, 1½ to 2 inches thick, is laid over the whole surface of the cellar, with due care that sufficient descent is given to carry the water to the drain. When the cement is thoroughly dry, it is given a coat of asphalt, shown at *d*, over the entire surface of the floor, and through the walls at *e*, then up the outside of the wall at *f*, to the earth line or just below it.

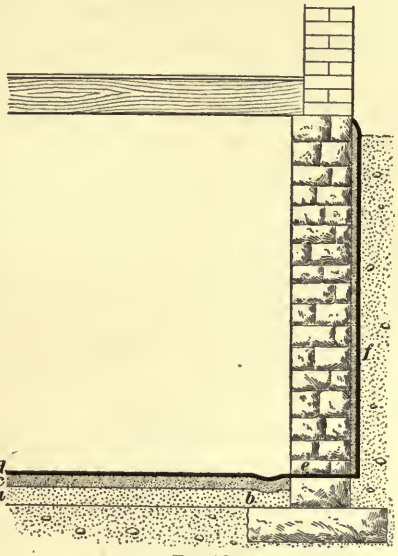


FIG. 53.

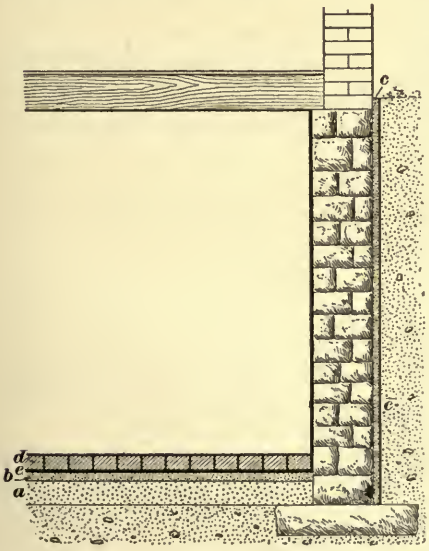


FIG. 54.

137. Another method of securing a dry cellar is shown in Fig. 54.

The cellar bottom is leveled up smooth and even, spread with sand, as shown at *a*, to the depth of 4 or 5 inches, and well beaten down with a rammer to make it firm and hard. It is better to have the sand damp, as it packs better. On top of this the whole surface is covered with 1½ inches of Rosendale or Portland cement *b*, which is carried well against the walls. The outside of the walls is then coated 1 inch thick with cement *c*, which is carried up to the ground line. When this is dry, the cellar bottom and outside walls are covered with hot asphalt, as shown at *e*. A pavement of hard-burned, good, even brick, dipped in asphalt, is then laid over the entire cellar, as seen at *d*.

138. When the cellar floor is only moderately damp, and there is no additional moisture after rains, a good bottom may be prepared by covering the cellar bottom with mortar composed of 6 parts of sand, and 1 part each of cement and lime. On this are laid 6″ × 6″ sleepers, preferably locust, and in the spaces between the sleepers, concrete is filled in. On this the wooden flooring is laid.

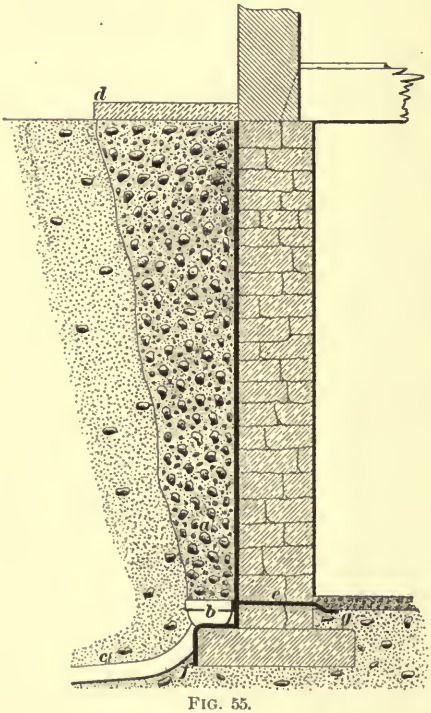


FIG. 55.

139. Another simple method of excluding moisture from cellars, is shown in Fig. 55. The excavation *a* is made wider than the building, so that there will be a foot or 10 inches left between it and the foundation wall. A V-shaped

or semicircular tile drain, shown at *b*, should be placed at the bottom of this trench, after the wall is built, and connected with a horizontal drain, emptying either into the cesspool or sewer. The trench *a* should then be filled with loose stone, coarse gravel, and sand. If the top, for about 2 or 3 feet from the building, is then covered with stone flagging or cement *d*, it will assist greatly in keeping the walls dry. If the soil around the building is drained in this way, and the wall is coated with asphalt as shown at *e*, a perfectly dry wall can be obtained. The asphalt should be carried down to the bottom of the footings, as at *f*, and through the wall to the under side of the cellar floor, as seen at *g*.

140. A durable composition for a cellar bottom is made of 60 parts asphalt, 10 parts coal tar, and 30 parts sand. It should be used while hot. Cement and asphalt in equal parts are also used, and found durable for cellar bottoms. The ingredients should be mixed in a large pan or boiler, over a fire, and, when thoroughly mixed, spread over the surface.

SHORING, NEEDLING, AND UNDERPINNING.

141. When the foundations of a building, whether new work or an alteration, extend below the foundation walls of adjoining property, *shoring*, *needling*, and *underpinning* must be resorted to, in order to protect the walls of the existing structure.

The contractor is usually held responsible for the successful carrying out of this part of the work, and, consequently, there are in all the large cities firms or individuals who make a specialty of shoring and underpinning. The architect, however, should be familiar with the methods used, and should see that all due precautions are taken for safety, and that all the beams, shores, braces, and posts are sufficiently strong to safely carry the loads imposed on them.

SHORING.

142. **Shoring** is a method of temporarily supporting the walls of a building by means of posts or struts set at an angle, to keep the wall from *tipping* or *bulging* while the

foundations are being carried down, or during the *needling* and removal of the lower portion of the wall.

When columns or girders are to be used in place of brickwork, the method of shoring the wall for the purposes above mentioned is shown in Fig. 56. Grooves, or sockets, are first cut in the wall, as shown at *a*, and in these the angle braces, or *shores*, *b*, *b* are inserted. These are also called *spur braces*, and when tightened up by means of screw jacks, instead of the wedges *d*, they are known as *pumps*. The lower ends of the shoring timbers rest on a timber crib *c*, supported on the ground. At least two sets of braces are usually put in, one to support the wall, as low down as possible, and the other placed higher up, to keep it from bulging. The platform must be made large enough to distribute the pressure brought upon it over the ground, and the shores should be well wedged with iron or oak wedges, as shown at *d*. The timbers carrying the ends of the braces should be adjusted, to the proper inclination by means of wedges, as shown at *e*. It is customary to allow a space of about 5 feet between braces, and all piers and chimneys should be separately shored.

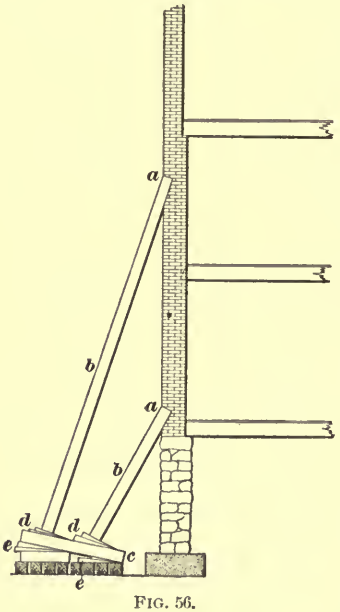


FIG. 56.

The foundations should be removed in small portions at a time. When three sets of braces, or shores, are in place the wall should be underpinned, as hereafter described, after which the shores over it may be moved along; two sets, however, must always be kept in place.

143. Shoring is often resorted to when it is necessary to hold up the corner of a building, to build a pier,

or set a column under it. When a girder is placed under the upper part of a wall, *needling* is necessary, as being attended with less risk.

NEEDLING.

144. When a wall already built is supported on beams or *needles* placed transversely through holes cut in the wall, as shown at *b*, Fig. 57, and supported at each end by posts, jack-screws, or *pumps*, as shown at *f*, it is said to be *needled;* and the operation of preparing it is called **needling.**

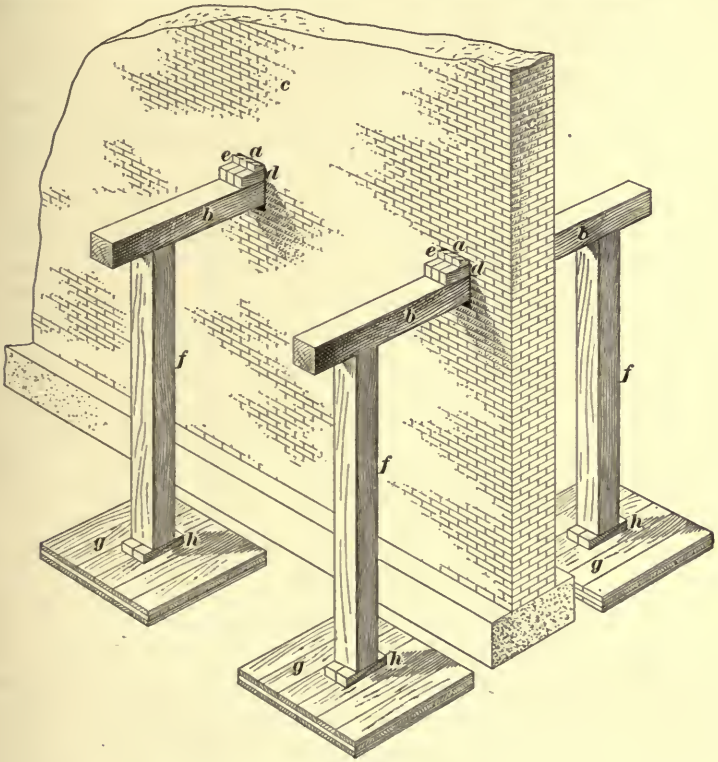


FIG. 57.

145. Fig. 57 shows how a wall is held up by needles in order that a new wall may be built under the upper portion, or columns and girders placed to support it.

At *a* are shown the holes in the wall, cut at intervals to receive the needles *b*; these needles consist of heavy timbers to carry the upper wall *c*. Where the needle enters the hole in the wall, small cross-beams *d* are laid on the upper side, and wedged in with oak or iron wedges, as shown at *e*, in order to secure a larger and more even bearing on the wall. At the inner and outer ends of the needles, heavy perpendicular timbers *f* are placed to support the needles and carry the weight of the wall. The foot or ground bearing of these timbers is formed by three courses of heavy plank, shown at *g*, crossing each other at right angles to spread the weight over more surface. Wedges *h*, *h* are driven under the foot of each upright, forcing the ends of the needles up until they show a slight downward deflection, or bending at the center, thus indicating that the weight of the wall is carried on the needle. As soon as the needles carry the wall, the intermediate portions may be torn out, and the columns and girders, or other substructures, are put in place, or the excavation to the lower level begun.

In cases where the ground is soft or compressible, sheet-piling is placed around the foot of the uprights, to hold the ground in place.

146. Very frequently, especially for heavy work, when a high wall is to be underpinned, steel beams are used for the needles, jack-screws are placed under the foot of the uprights, or a crib of heavy beams is built up in place of the upright posts.

UNDERPINNING.

147. The new wall under the needle holes is built up from the lower level, between and around the needles. It is customary in first-class work, to place two layers of stone, dressed top and bottom, between the old and new wall. Iron wedges are then driven between these stones, in opposite pairs, one from the inside and the other from the outside, care being taken to drive them evenly from both sides, or the wall may tip or bulge. The wedges are driven until the weight of the wall is carried on them and not on the needles. This

can be readily seen by the straightening of the needles when relieved of the load. The jack-screws are now loosened, or the wedges under the uprights eased up; the uprights are taken away, the needles are removed, and the holes filled up.

148. Underpinning operations should be carefully performed. The underpinning should be done as quickly as possible after the shores or needles are in place, so as not to require their support for a longer time than necessary. The needles or shores, however, should not be removed until the cement in the new work has had ample time to set.

BRACING.

149. When adjoining buildings have been built originally with party walls, or walls supporting the floorbeams of two buildings, and one of these buildings is to be torn

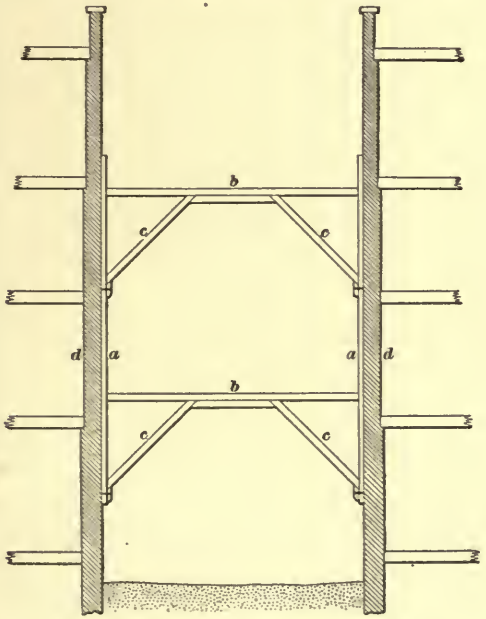


FIG. 58.

down, the adjacent walls should be prevented from falling by spreading braces or inclined shores. When there are

buildings on each side of the lot on which the new building is to be erected, the walls of these structures may be supported by spreading braces.

150. When the distance is not more than 25 feet, the braces may be arranged as shown in Fig. 58. At *a* are $6'' \times 12''$ uprights against the walls *d*, to distribute the bearing of the braces; at *b* are the spreaders, and at *c* the angle braces, all of which may be $8'' \times 8''$ timbers.

When the old buildings are from 40 to 50 feet apart, the spreading braces should be trussed, as shown in Fig. 59.

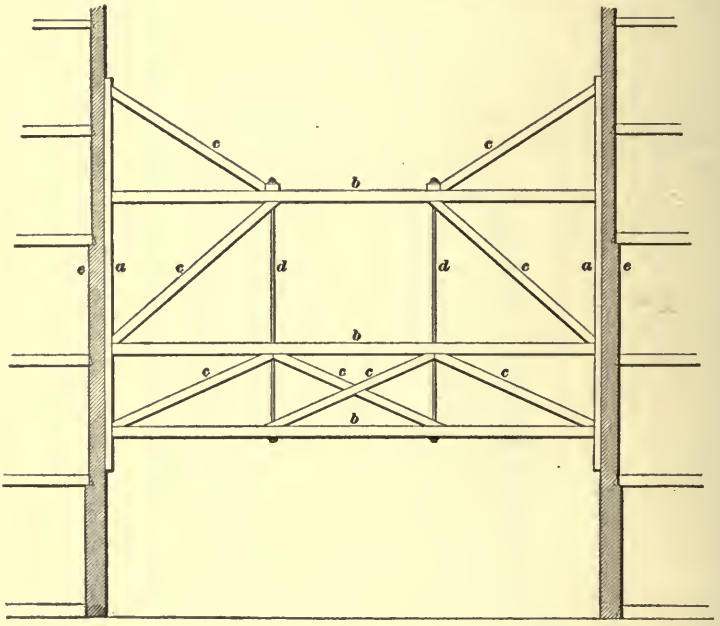


FIG. 59.

The $6'' \times 12''$ uprights are shown at *a* against the walls *e*; the $10'' \times 10''$ spreaders at *b*; the $8'' \times 8''$ struts and braces at *c*; and the vertical iron or steel ties at *d*. It is preferable to use iron or steel rods for these vertical ties, as they can be readily screwed up, and thus overcome any sagging that may occur in the joints of the truss. One truss should always be placed in the front, another in the rear of the

building; and an intermediate one every 25 feet between will generally be found sufficient.

When there is no wall opposite the building to be braced, inclined shores or spur braces may be arranged as shown in Fig. 56, but with a greater inclination. Iron or oak wedges should be used at the lower ends of the braces, to give them a proper bearing. These spreading braces are usually built by the carpenter, but it is essential for the architect to know how they should be constructed.

MATERIALS USED IN MASONRY CONSTRUCTION.

LIME, CEMENTS, SAND, AND MORTAR.

151. All walls, whether of brick or stone, should be laid in cement mortar, or lime-and-cement mortar mixed in the proportions hereafter given. If the soil is wet or damp, cement mortar should be used, but for ordinary sand, clay, or gravel, cement and lime mortar fulfils the requirements, and where foundation walls are above the level of the surrounding ground, good lime mortar may be used.

LIME.

152. Pure, rich, or "fat" lime is the product of the calcination, or burning, of limestone or marble. By this burning, the carbonic acid and water are driven from the stone in the form of vapor, and the residue is ordinary lime. Pure water-slaked lime has no cohesive power, but on the addition of sand, the carbonic acid in the atmosphere is slowly absorbed by the hydrates in the lime, and finally they resume the crystalline form of the original carbonates, and solidify around the particles of sand with which they are in contact. Hence the mortar on the outside of a wall hardens first, and this hardening process continues until the whole mass of mortar in the wall is affected.

Both cement and lime should be kept in a dry place, as exposure to the air causes lime to air-slake. The action of the atmosphere reduces the lime to a powder, as when slaked by water, but without heating and but little swelling.

153. **Hydraulic limes,** containing from 10 to 20 per cent. of silicates, when mixed into mortar, will harden in either air or water, but somewhat slowly under water. They slake to some small extent, but not rapidly, and harden through chemical action through the whole mass at the same time. These mortars should not be allowed to stand any great length of time, as they take an initial set, which when disturbed by remixing, materially diminishes their ultimate strength. Hydraulic lime mortar is usually made of 1 part hydraulic lime to 3 parts sand.

CEMENTS.

154. The ordinary cements, known as the Rosendales, comprising the Cumberland, Round Top, James River, Louisville, and others, are manufactured from natural cement stones existing in most of the states, and are known as light, quick-setting cements. These stones are calcined in a kiln; the product is then very finely ground and packed in barrels or sacks. For mortar they should not have more than 3 parts of sand to 1 of cement.

155. What are known as the heavy, slow-setting cements are almost entirely artificial products; these are called Portland cements, such as the German, English, French, and American brands. They are composed of pure clay and pure lime, combined in certain definite proportions determined by experiment, thoroughly mixed, and calcined at a very high temperature, then ground to a fine powder, and carefully packed in strong, light barrels, generally lined with paper to prevent any possible absorption of moisture. These cements will stand 4 parts of sand to 1 of cement, for cement mortar.

156. As to different cement brands, we must first be guided by tests that have been made, and select that one which seems best suited for the purpose in view; and in addition, simple tests should be made on delivery. All broken barrels should be rejected, especially if the cement is to be stored for any length of time, as by exposure to the air it will "take a set" and become useless.

It is well to test a number of barrels by feeling, in order to determine the fineness to which it is ground. A little experience will enable this to be determined by the sensitiveness of the touch. In addition, small cakes of mortar made with good sand and cement, in proportions used on the work, will give a very good idea of its setting qualities, either in air or water. In general, the Portland cements can be relied on, especially if made by the standard companies, who cannot afford to put inferior grades on the market.

SAND AND ITS SUBSTITUTES.

157. The sand used in making mortar should have no mixture of clay or loam in it, but should be clean and sharp particles of quartz or other disintegrated rock. These particles enter readily into the irregularities of the surfaces of stone and brick, thus forming a more perfect bond.

Sea sand or salt water should never be used in the preparation of mortar, as the mortar will not dry properly, and the salt in the sand, when united with the carbonate of lime, forms an efflorescence or deposit on the outside of brickwork or stonework. The grains of sea sand are globular in form, owing to the constant rolling and washing of the waves, and they do not unite readily with the lime or cement.

Pulverized brick, cinders, furnace slag, and scoriæ are used as substitutes for sand in making mortar, where sand is scarce. It is generally admitted that these substances are as good as, if not superior to, sand in making good mortar; the cost of pulverizing, however, adds to the expense, so that they are seldom used where good sand is obtainable.

The addition of a small quantity of brick dust to the

ordinary lime-and-sand mortar seems to give it the property of setting under water. It also acts as a preventive of disintegration when the mortar is exposed to the elements.

MORTAR.

158. Lime Mortar.—This mortar is prepared in much the same way as pure cement mortar. For mixing lime mortar, a bed of sand is first made in a mortar box, and the lime is distributed as evenly as possible over it, both the lime and sand being first measured in order that the proportion specified may be obtained.

The lime should then be slackd by pouring on water, and covered with a layer of sand, or, preferably, a tarpaulin, to retain the vapor given off while the lime is being slaked or converted into hydrates of lime by action of the water. Additional sand is then added if necessary, until the mortar contains the proper proportions. The proportion of sand to lime usually specified, and called for by the New York and Boston building laws, is 3 of sand to 1 of lime. If, however, both the materials are of good quality—that is, if the lime slakes freely, becomes a fine, impalpable powder, resembling flour in texture, and perfectly free from foreign matter, and the sand is clean and sharp—1 part to 4 is sufficient; but more sand than this is injurious.

It is considered better to make lime mortar in large quantities; then to leave it in piles for use as it may be needed, after stirring and tempering.

159. Cement and Lime Mortar.—For this mortar, the cement, lime, and sand should be well mixed together before water is added, as described for cement mortar. Cement and lime mortar should be used shortly after it has been mixed, before the cement *sets*.

160. Cement Mortar.—This should be mixed in the proportion of from 3 to 4 parts of sand to 1 of cement. It is advisable that these parts should be actually measured in

barrels, and the architect should see that this is done. (It is a common practice with many builders to have one laborer shovel cement or lime, while three or four of the strongest men are shoveling sand, it being called one of cement, to three or four of sand; this is a very unreliable method of measuring.) After the sand and cement are thrown on the platform, they must be thoroughly mixed by shoveling the two materials together, at least twice, so that the cement may be thoroughly incorporated with the sand. A little lime may be added in winter to prevent freezing. Sufficient water is now added to make a stiff paste, and the mortar must be immediately conveyed to the work and used, as the cement *sets*, or hardens, very rapidly, and after it is once hard the mortar cannot be used again.

161. Mortar Colors and Stains.—Artificial coloring, in mortar, has been known for hundreds of years; but its general use dates from a comparatively recent period.

There are two totally different architectural objects aimed at in using colored mortar; one is to get the effect of a mass of color by concealing the joints; the other is to use a contrasting color to emphasize the joints.

Common brick lose much of their rough effect when mortar of the same color as the brick is used, and the chipped or uneven edges do not show as plainly as they do when the bricks are laid in white mortar.

162. Most of the mortar colors and mineral pigments are sold either as a dry powder or in the form of a pulp or paste. Pulp colors seem to mix better with the mortar than dry colors, and are therefore preferable for the better class of work. Mortar colors, whether used in dry or pulp form, should never be mixed with lime until the lime has been slaked at least twenty-four hours. The color should, however, always be mixed very thoroughly with the lime putty before any sand is added; if the work is very fine, the colored mortar putty should be strained through a coarse sieve. When a quantity is required, the color should be

mixed with the sand and set aside in barrels, and the cement added when required for use.

The colored mortar looks different in the bed than when dry. The final color can be seen by taking a little from the bed and permitting it to dry thoroughly.

BRICKS AND BRICK MAKING.

INTRODUCTORY.

163. **Brick** may be called an artificial stone, manufactured in small pieces for convenience in laying. The principal ingredients in brick are clay and protoxide of iron. Other substances that form part of ordinary clay either do no good or are absolutely harmful, carbonate of lime, in any large quantity, rendering the clay absolutely unfit for making brick. Sand or silica should not exist in any excessive quantity, as an excess of sand renders the brick too brittle and destroys cohesion. Twenty-five per cent. of sand is considered a good proportion.

The protoxide of iron in the brick clay causes the red color in the brick after burning, the coloring varying with the proportion of iron. With more intense heat, the brick, if slightly fusible, may be vitrified externally and become a sort of greenish blue. The presence of magnesia or a small percentage of lime in the clay will change the red color, produced by iron, to a cream or buff. The mottled, or Pompeian brick, now largely used, have the mottled effect produced by the use of coloring matter in the clay, or by mixing clays of a different chemical composition.

HAND-MADE BRICK.

164. Many of the common brick, especially in the smaller towns and cities, are made by hand.

The clay is thrown into a circular pit, where it is mixed with water, and tempered with sand or ashes by means of a tempering wheel, attached to a long lever and worked by

horsepower. When the clay becomes soft and plastic, it is taken to the molding table and pressed into the molds by hand.

The molds are either dipped in water (called *slop molding*) or in sand (called *dry molding*) to prevent the clay from adhering to the mold. The sand-molding process gives cleaner and sharper brick than the slop molding. After the bricks are shaped in the mold, they are laid in the sun or in a dry house for three or four days, after which they are stacked in kilns and fired.

MACHINE-MADE BRICK.

165. Where bricks are made on a large scale the work is now done by machinery, by three different processes, known as the *soft-mud*, the *stiff-mud*, and the *dry-clay* processes.

166. Soft-Mud Process.—The clay, after being dug from the clay bank, is thrown into a pit, usually 6 feet deep, and 8×12 feet in area, lined with plank; water is then turned into the pit, and the clay is soaked for twenty-four hours. It is usual to provide three pits, so that the clay may be soaking in one, while the second is being emptied and the third filled. The clay is thrown out upon an endless chain, which carries it along to the machine, into which it falls. The upper part of the machine contains a revolving shaft on which arms are placed. These arms break up and work the soft clay, after which it falls to the bottom of the machine; here revolving blades force it forward, and a plunger having an up-and-down motion, forces the clay into a mold immediately under the plunger. When the mold is filled, it is either drawn or forced out on a shelf or table; another mold is then placed under the machine, and the filled mold is emptied by hand and the brick taken to the drying yard.

167. Stiff-Mud Process.—The difference between a *soft-mud* and a *stiff-mud* process is, that in the latter, the clay is first thoroughly ground, and just enough water is

added to make a stiff mud. After this mud goes through the pug mill, it is placed in a machine having a die the exact size of the brick required. The opening in this die is made the size of either the end or side of a brick. The machine forces a continuous bar of clay through this die, and, as it emerges, it is automatically cut in the form of a brick, and then taken to the drying yard. The soft brick are placed in rows in a yard covered by a rough shed with the sides open, where they are sun or air dried for three or four days. When properly dried they resemble somewhat the "adobe" brick, formerly used for constructing houses, and still used in some of the Southwestern states and territories, and also in Mexico and Central America.

168. Dry-Clay Process.—The third process, and one much used, is known as the *dry-clay* process. The clay is used in this method just as it comes out of the bank, and is apparently perfectly dry. It contains, however, from 7 to 10 per cent. of moisture.

The clay is first mined, either by hand or steam shovel, as circumstances may require. It is then usually stored under cover, in order that a supply may be constantly on hand, and also that it may further dry and disintegrate. In many cases, two or more grades of clay are mixed together in proper proportions, determined by trial, as the clay is thrown in the *dry-pan*, which is a circular machine about 4 feet in diameter, and 2 feet deep, having a perforated metal bottom. In this pan are two wheels which revolve on horizontal axles. Between these wheels and the bottom of the pan, which also revolves, the clay is ground; it then drops through the holes in the bottom of the pan to a wide belt, which passes above an inclined screen on which the clay falls. Such portions of the clay as are sufficiently ground pass through the screen on to another belt, while the coarser particles pass into the dry-pan to be ground over, and again carried to the screen for sifting.

The belt carries the finely ground clay to a mixing pan, which by constant agitation thoroughly mixes the particles.

The clay falls from the mixing pan into the hopper of the pressing machine, and thence into the molds. The loose clay fills evenly steel boxes the same width and length as the finished brick, but much deeper. Steel plungers, forced under great pressure into these boxes, compress the clay until the requsite thickness is obtained. The pressed brick is then pushed on a table, and from this the bricks are placed on a barrow or car and taken to the kiln.

Molded bricks are made in the same way, the difference being that the box is made to give the shape of the brick required. In most of the dry or pressed clay brick machines, a small jet of steam is admitted into the clay just before it enters the mold, in order to slightly moisten it, and cause the particles to cohere better.

Whenever the term *pressed brick* is used, it should mean the brick made by the dry process. There are many so called *dressed* or *face brick*, however, that are made by *repressing soft-mud brick.*

BURNING THE BRICK.

169. When either the *hand-made*, *soft-mud*, or *stiff-mud* processes are used, the bricks, after drying, are built in a large mass, or kiln, containing from 100,000 to 300,000 bricks. *Eyes*, or flues, are left at the bottom as receptacles for fuel. The bricks are laid loosely together in order to allow the heat to pass in and around them. When ready, the fire is started, slowly at first, but afterwards increased to an intense heat; and after burning for a period determined partly by the fuel used, but mainly by experience, the fires are allowed to die out gradually.

On opening a brick kiln after burning, the quality of the brick therein contained may be divided into four classes: First, the extreme outside brick, which are burnt so little that they are almost worthless. Second, a layer inside the above, in which the brick are underburned and soft; these are called *pale* or *salmon brick*, and are unfit for foundation or face work, but are used for filling in between stud

partitions, and sometimes between harder brick in the inside of walls, although their use for this purpose is not recommended. In the third layer of the mass forming the kiln, is found a class of brick well burned, hard, well shaped, and of a good red color. This kind of brick is good for any purpose. The brick in the fourth or inner layer of the kiln, just above the flues, are overburnt, very hard, very brittle, and usually distorted, cracked, and even vitrified; they should not be used in any structure subject to shock, but are often used for paving brick.

CLASSES OF BUILDING BRICK.

170. Common Brick.—The term common brick includes all those that are intended for constructional, and not for ornamental purposes, and have no special pains taken in their manufacture. There are three grades of common brick, termed according to their position in the kiln, *arch* or *hard* brick, *red* or *well burned* brick, and *soft* or *salmon* brick.

171. Stock brick are a hand-made brick intended for face work; greater care has been taken in the manufacture and burning than with common brick. They are used extensively for the outside facing of factories, machine shops, and the cheaper class of private dwellings. In the Eastern states they are sometimes called *face* brick.

172. Pressed Brick or Face Brick.—These are the brick made in a dry-press machine, or that have been repressed. They are usually very hard and smooth, with sharp angles and corners, and true sides and beds. They cost from two to five times as much as common brick, and are, therefore, usually laid only in the face of the wall.

Special forms of pressed brick are called *molded*, *gauged*, *arch*, and *circle brick*. Molded and ornamental brick are now made in a great variety of forms and patterns, so that cornices and moldings may be made entirely of brick.

If the architect requires special patterns of molded brick

to carry out his designs, most of the larger companies manufacturing pressed brick will make the special shapes so desired, if drawings are furnished. These should be drawn to a large scale, and full-sized details should be given.

173. Arch bricks for circular or segmental door and window openings in brickwork should be made in the form of a truncated wedge, that is, a wedge with the sharp end cut off.

The walls of circular towers, bay windows, etc. are faced with what are known as **circle brick,** or brick molded to the shape of the circle desired.

The radius of the bay or tower should always be given when ordering either kind.

174. Firebrick.—These brick are used for the lining of furnaces, lime kilns, fireplaces, and tall chimneys in manufactories. They should be free from cracks, of homogeneous composition and texture, uniform in size, of a regular shape, easily cut, and not fusible. They are usually somewhat larger than the ordinary building brick.

Firebrick are made from a mixture of about 50 per cent. raw flint clay and 50 per cent. plaster clay. The brick are made by the stiff-mud and dry-press processes, and by the soft-mud process, hand molded. It is generally thought that the last process gives the most perfect brick.

175. Glazed and **enameled brick** are used largely for lining water-closet and bathroom walls, the wainscoting of halls and staircases, and in many cases for the entire walls of stores and restaurants, hospitals, public waiting rooms, and markets, or wherever a non-absorbent surface that is clean and light is desired. They can be used for external as well as for internal purposes, as they will stand the most severe changes of weather, reflect light, acquire no odor, are impervious to moisture, and are fireproof.

176. The term *enameled* is given to all bricks having a glazed surface. There exists, however, quite a marked difference between a glazed brick and an enameled brick.

A genuine enameled brick has the enamel fused into the brick without any intermediate coating, and the enamel is opaque in itself. The glaze, on the contrary, is produced by first covering the unburned brick with a "slip," as it is called, and then with a second coat of a transparent glaze closely resembling glass.

The enameled surface can be distinguished from one that is merely glazed by chipping off a piece of the brick. The enameled brick will show no line of demarcation between the body of the brick and the enamel, while the glazed brick will show a layer of slip between the glaze and the brick. The bricks are enameled or glazed only on one face or on one face and one end.

The true enameled brick costs more than the glazed brick, as it is more difficult to manufacture; but, owing to the enamel being a part of the brick itself, an enameled brick is more desirable than a glazed brick, and will not chip or peel as readily.

177. The *slip* used in the manufacture of glazed bricks is a composition of ball clay, pulverized kaolin, flint, and feldspar. The unburned brick is first coated on the side to be glazed with this composition, which adheres to and covers the clay, and also receives and holds the glaze, which is put on very thin. After burning, the glaze leaves a transparent body covering the white slip.

178. The real enameled brick are made from a certain kind of clay that usually contains a considerable quantity of fireclay. The enamel is applied either to the unburned brick or after it is burned. It is claimed that the latter method produces the best brick.

After the enamel is applied, the brick is burned and the enamel fuses and unites with the brick in the same manner that the glaze on a teacup or saucer unites with the material composing the cup or saucer. It is not transparent and shows its own color.

For many years all the glazed and enameled brick

were made in England, but there are now several factories in this country. The English brick are 3 inches $\times 9$ inches $\times 4\frac{1}{2}$ inches. Most of the American factories make the American standard size, which is $8\frac{1}{4}$ inches $\times 4$ inches $\times 2\frac{1}{4}$ inches, but some of them adhere to the English standard.

179. Paving brick do not come strictly within the province of the architect, but, as he may have occasion to use them for paving driveways, etc., it is well to have some knowledge of them. These paving bricks are also used sometimes for paving the flat roofs of office buildings, apartment houses, etc., and when laid in cement make a durable fireproof roof covering.

It is usual to make paving brick by the stiff-clay process, and the brick, after being cut from the bar, are generally —although not always—repressed to give them a better shape. Shale clay and about 25 to 30 per cent. of fireclay are used in making paving brick. In order to stand frost and wear, paving brick require to be very hard, and therefore must be burned to vitrification, or until the particles of the body of the brick have been united in chemical combination by means of heat. Some varieties of paving brick are made without burning. They are manufactured by a process of intimately mixing materials of the nature of cement, and squeezing the mixture by hydraulic pressure. A serviceable paving brick is made from ground furnace slag, lime, etc. mixed with cement; when the cement is set, the brick is as hard as stone.

180. In order to enable paving brick to withstand the various sources of wear and disintegration to which they must be exposed, in a street or driveway, or even on a roof, they must be very compact in texture, and must have the qualities of vitrification and toughness, and should not be so distorted in shape as to lie unevenly in the pavement. This crushing strength should not be less than 8,000 pounds per square inch. Paving brick should absorb little or no water,

and, when thoroughly vitrified, the limit of absorption should not be more than 4 per cent., and paving bricks are made that do not absorb more than 1 per cent. If the bricks absorb water, frost will soon crack them, and they will quickly be destroyed.

SIZE OF BRICKS.

181. In this country, unfortunately, there is no legal standard regulating the size of brick, and the dimensions vary not only with the maker, but also with the locality. In the New England states, the average size of common brick is about $7\frac{3}{4}$ in. $\times 3\frac{3}{4}$ in. $\times 2\frac{1}{4}$ in.; New York and New Jersey brick will run about 8 in. $\times 4$ in. $\times 2\frac{1}{2}$ in., and the walls laid in them will run 8, 12, 16, and 20 inches in thickness for 1, $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ bricks. Most of the Western common brick measure $8\frac{1}{2}$ in. $\times 4\frac{1}{8}$ in. $\times 2\frac{1}{2}$ in., and the thickness of the walls measures about 9, 13, 18, and 22 inches for thicknesses of 1, $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ bricks. On the seacoast of some of the Southern states, the brick are made with a large percentage of sand, and will average 9 in. $\times 4\frac{1}{2}$ in. $\times 3$ in.

Most manufacturers of pressed brick use the same size mold, hence pressed brick are more uniform in size. They are generally $8\frac{3}{8}$ in. $\times 4\frac{1}{8}$ in. $\times 2\frac{3}{8}$ in. Pressed brick are also make $1\frac{1}{2}$ inches thick. There is a form used frequently, known as Roman or Pompeian brick, the size of which is 12 in. $\times 4$ in. $\times 1\frac{1}{4}$ in.

It is important that pressed brick should be made of such size that two headers and a joint will equal one stretcher, in order that a good bond may be secured; and it is also desirable that the length of a brick should equal three courses when laid.

The *weight* of bricks varies considerably with the material used, and also, of course, with their size. Common brick will average about $4\frac{1}{2}$ pounds each, while pressed brick, owing to their greater density, will weigh from 5 to $5\frac{1}{2}$ pounds.

STRENGTH AND QUALITY OF BRICK.

182. An architect should, if possible, examine the brick to be used in a building before they are laid in the wall, and they should meet the following requirements:

1. They should be sound, free from cracks or flaws, and from stones and lumps of any kind, especially pieces of lime.

2. The bricks must be uniform in size, with sharp angles and edges, and the surfaces true and square to each other; this insures neat work.

3. Good building brick should be quite hard and well burned. A simple, and generally satisfactory test for common brick is to strike two of them together, or to strike one with the edge of a mason's trowel; if the brick gives a ringing sound it is generally sufficiently strong for any ordinary work. A dull sound shows the brick is soft or shaky.

4. The quantity of water absorbed is also important. A good brick should not absorb more than one-tenth its weight in water. A good test is to weigh the brick first, then immerse it in water for twenty-four hours, and weigh it again. From the increase in weight the percentage of water it has absorbed may be found. Very soft underburned brick often absorb from 25 to 35 per cent. of water. Weak, light-red brick, often used in filling the interior of walls, will absorb about 20 to 25 per cent., while the very best brick may absorb not more than 5 per cent., and should, if possible, be used for outside walls and foundation walls and piers.

5. Brick that are suitable for piers and the foundations of heavy buildings should not break under a crushing load of less than 4,000 pounds per square inch.

6. The transverse strength of a brick is quite as important as the crushing strength. A good brick, 8 inches long, 4 inches wide, and $2\frac{1}{2}$ inches thick, should not break under a center load of less than 1,600 pounds, the brick lying flat, supported at each end only, and having a clear span of 6 inches, and a bearing at each end of 1 inch. A first-class brick will carry 2,250 pounds in the center and not break. Tests have been made with brick that carried 9,700 pounds before breaking.

BRICK MASONRY.

THICKNESS OF BRICK WALLS.

183. Before taking up the subject of bricklaying, the student should become acquainted with the laws for the **thickness of walls** in this country. For this purpose, an extract is given from the building law of New York, relating to the thickness of brick walls in proportion to their height. The laws of other cities do not vary materially from the New York law, and it can be safely taken as a standard.

184. Dwelling Houses.—"The basement walls of dwelling houses not over 35 feet in height and not over 20 feet in width shall not be less than 12 inches thick, if of brick; the other walls shall not be less than 8 inches thick; but no *party* wall in any such building shall be less than 12 inches thick. (See Fig. 60.)

"The walls of all dwelling houses, whether called tenement houses, apartment houses, flats, hotels, or other buildings, which are to be used for residence purposes, and are 26 feet or less in width between walls, and also the walls of schoolhouses over 35 feet in height and not over 50 feet in height, shall not be less than 12 inches thick above the foundation wall; but no wall shall be built having a 12-inch thick portion measuring vertically more than 50 feet. [See (*a*) and (*b*), Fig. 61.]

"If over 50 feet in height and not over 60 feet in height, the walls shall not be less than 12 inches thick above the basement, if a high-stoop house, and not less than 16 inches in the first story if not a high-stoop house. [See (*a*) and (*b*), Fig. 62.]

"If over 60 feet in height and not over 75 feet in height, the walls shall not be less than 16 inches thick to the height of 25 feet, or to the nearest tier of beams to that height, and from thence not less than 12 inches thick to the top. (See Fig. 63.)

"If over 75 feet in height and not over 85 feet in height, the walls shall not be less than 20 inches thick to the height

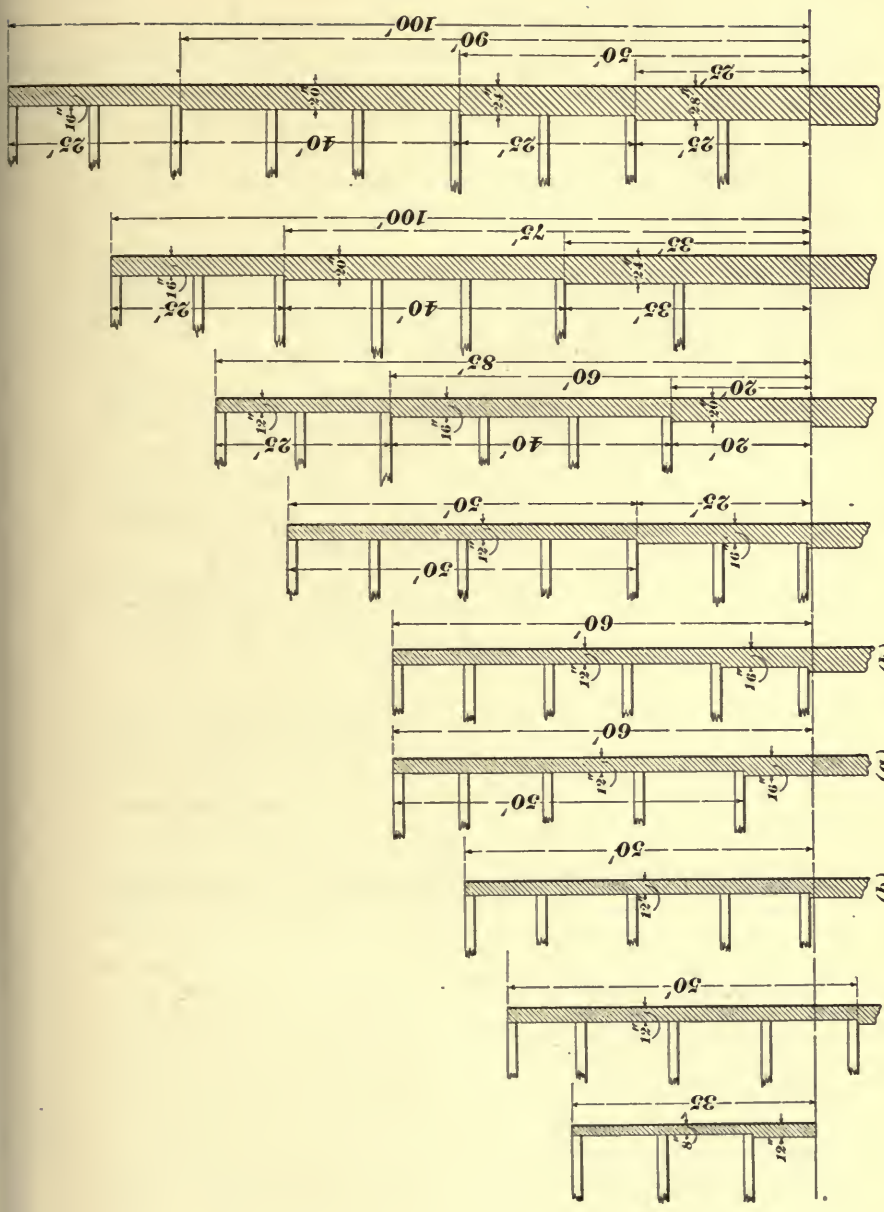


FIG. 66.

FIG. 65.

FIG. 64.

FIG. 63.

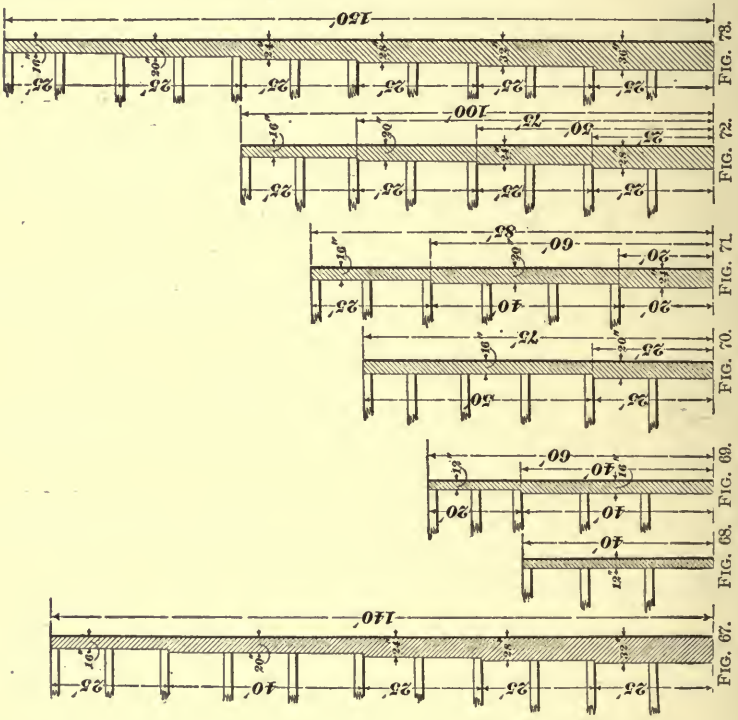
FIG. 62.

FIG. 61.

FIG. 60.

of 20 feet, or to the nearest tier of beams of that height, thence not less than 16 inches thick to the height of 60 feet, or to the nearest tier of beams of that height, and from thence not less than 12 inches to the top. (See Fig. 64.)

"If over 85 feet in height and not over 100 feet in height, the walls shall not be less than 24 inches thick to the height of 35 feet, or to the nearest tier of beams to that height, thence not



less than 20 inches thick to the height of 75 feet, and from thence not less than 16 inches thick to the top. (See Fig. 65.)

"If over 100 feet in height and not more than 115 feet in height, the walls shall not be less than 28 inches thick to the height of 25 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 50 feet, or to the nearest tier of beams of that height; thence not less than 20 inches thick to the height of 90 feet, or to

the nearest tier of beams of that height, and from thence not less than 16 inches thick to the top. (See Fig. 66.)

"If over 115 feet in height, each additional 25 feet in height, or part thereof, next above the curb, shall be increased 4 inches in thickness, the upper 115 feet of wall remaining the same as specified for a wall of that height. (See Fig. 67.)

"Eight-inch partition walls may be built to support the beams in such buildings in which the distance between the walls is not over 33 feet, providing that no clear span is over 26 feet; but no such brick partition wall shall be built having an 8-inch thick portion measuring vertically more than 50 feet.

185. "The walls of all **warehouses, stores, factories,** and **stables** 25 feet or less in width between walls shall not be less than 12 inches thick to the height of 40 feet. (See Fig. 68.)

"If over 40 feet in height and not over 60 feet, the walls shall not be less than 16 inches thick to the height of 40 feet or to the nearest tier of beams to that height, and from thence not less than 12 inches to the top. (See Fig. 69.)

"If over 60 feet in height and not over 75 feet in height, the walls shall not be less than 20 inches to the height of 25 feet or to the nearest tier of beams to that height, and from thence not less than 16 inches thick to the top. (See Fig. 70.)

"If over 75 feet in height and not over 85 feet in height, the walls shall not be less than 24 inches thick to the height of 20 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 60 feet, or to the nearest tier of beams to that height, and thence not less than 16 inches thick to the top. (See Fig. 71.)

"If over 85 feet in height and not over 100 feet in height, the walls shall not be less than 28 inches thick to the height of 25 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 50 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 75 feet, or to the nearest tier of beams to that height, and thence not less than 16 inches to the top. (See Fig. 72.)

TABLE 3.

THICKNESS OF WALLS IN INCHES FOR WAREHOUSES, ETC.

Height of Building.	City.	Stories.								
		1st.	2d.	3d.	4th.	5th.	6th.	7th.	8th.	9th.	10th.
Two Stories,	Boston,	16	12								
	New York,	12	12								
	Chicago,	12	12								
	Minneapolis,	12	12								
	Memphis,	18	13								
	Denver,	13	13								
Three Stories,	Boston,	20	16	16							
	New York,	16	16	12							
	Chicago,	16	12	12							
	Minneapolis,	16	12	12							
	Memphis,	22½	18	13							
	Denver,	17	13	13							
Four Stories,	Boston,	20	16	16	16						
	New York,	16	16	16	12						
	Chicago,	20	16	16	12						
	Minneapolis,	16	16	12	12						
	Memphis,	27	22½	18	13						
	Denver,	21	17	13	13						
Five Stories,	Boston,	20	20	20	20	16					
	New York,	20	16	16	16	16					
	Chicago,	20	20	16	16	16					
	Minneapolis,	20	16	16	12	12					
	Memphis,	31½	27	22½	18	13					
	Denver,	21	21	17	17	13					
Six Stories,	Boston,	24	20	20	20	20	16				
	New York,	24	20	20	20	16	16				
	Chicago,	20	20	20	16	16	16				
	Minneapolis,	20	20	16	16	16	12				
	Memphis,	36	31½	27	22½	18	13				
	Denver,	26	21	21	17	17	13				
Seven Stories,	Boston,	24	20	20	20	20	20	16			
	New York,	28	24	24	20	20	16	16			
	Chicago,	20	20	20	20	16	16	16			
	Minneapolis,	20	20	20	16	16	16	12			
	Memphis,	40½	36	31½	27	22½	18	13			
	Denver,	26	21	21	21	17	17	17			

TABLE 3—*Continued.*

THICKNESS OF WALLS IN INCHES FOR WAREHOUSES, ETC.

Height of Building.	City.	Stories.									
		1st.	2d.	3d.	4th.	5th.	6th.	7th.	8th.	9th.	10th.
Eight Stories,	Boston,	28	24	20	20	20	20	20	16		
	New York,	32	28	24	24	20	20	16	16		
	Chicago,	24	24	20	20	20	16	16	16		
	Minneapolis,	24	20	20	20	16	16	16	12		
	Memphis,	45	40½	36	31½	27	22½	18	13		
	Denver,	30	26	21	21	21	17	17	17		
Nine Stories,	Boston,	28	24	24	20	20	20	20	20	16	
	New York,	32	32	28	24	24	20	20	16	16	
	Chicago,	24	24	24	20	20	20	16	16	16	
	Minneapolis,	24	24	20	20	20	16	16	16	12	
	Memphis,	49½	45	40½	36	31½	27	22½	18	13	
	Denver,	30	26	26	21	21	21	17	17	17	
Ten Stories,	Boston,	28	28	24	24	20	20	20	20	20	16
	New York,	36	32	32	28	24	24	20	20	16	16
	Chicago,	28	28	24	24	24	20	20	20	16	16
	Minneapolis,	24	24	24	20	20	20	16	16	16	12
	Memphis,	54	49½	45	40½	36	31½	27	22½	18	13
	Denver,	30	30	26	26	21	21	21	17	17	17

"If over 100 feet in height, each additional 25 feet in height, or part thereof, next above the curb, shall be increased 4 inches in thickness, the upper 100 feet of wall remaining the same as specified for a wall of that height. (See Fig. 73.)

"If there is to be a clear span of over 25 feet between walls, the bearing walls shall be 4 inches more in thickness than is heretofore specified, for every 12½ feet, or fraction thereof, that said walls are more than 25 feet apart."

186. Table 3 gives the thickness of walls required by law for warehouses, etc. in the six cities mentioned.

The tops of the second-floor beams are taken at 19 feet above the sidewalk, and the heights of the other stories are 13 feet 4 inches, including thickness of floors, as the New

York and Boston laws give the height of the wall in feet and not in stories.

The Chicago ordinances provide that the maximum heights of stories, in accordance with the thicknesses given in Table 3, are 18 feet in the first story, 15 feet in the second story, 13 feet 6 inches in the third, and 12 feet in the stories above.

BRICKLAYING.

187. To build any kind of a brick structure, so as to make a strong and durable piece of work, it is necessary to have a bed of mortar between the bricks. Brickwork consists therefore both of bricks and mortar. The strength and durability of any piece of work will depend on the quality of the brick, the strength and quality of the mortar, the way in which the bricks are laid and bonded, and whether or not the bricks are laid wet or dry.

188. The function of the mortar in brickwork is threefold:

1. To keep out moisture and by filling all crevices to prevent as far as possible excessive changes in temperature.

2. To unite the bricks into one mass.

3. To form a cushion to fill up any irregularities in the brick, and distribute the pressure evenly.

The first object is best attained by grouting or thoroughly *flushing* the work; the second depends largely upon the strength of the mortar, and the third is affected chiefly by the thickness of the joints.

LAYING COMMON BRICK.

189. Common brick should be laid in a bed of mortar at least $\frac{3}{16}$, and not more than $\frac{3}{8}$ of an inch thick. Every joint and space in the walls, not occupied by other material, should be filled with mortar.

The best way to allow for the thickness of the mortar joint is by the height of eight courses of brick, measured in the wall. This height should not exceed by more than 2

inches, the height of eight courses of the same brick laid dry. As common brick are usually quite rough and uneven, it is not always easy to determine the thickness of a single joint, but the variations from the above rule, in any eight courses that may be selected, should be very slight.

Pressed brick, being usually quite true and smooth, may be laid with a $\frac{1}{8}$-inch joint, though a $\frac{3}{16}$-inch joint is probably stronger, as it permits the use of more mortar, thus filling the joints better.

190. The best method of building a brick wall is as follows: The two outside courses are laid first; the mortar is spread with a trowel, along the top of the last course of brick, to form a bed for the brick to lie on; next some of the mortar is scraped against the outer vertical edge of the last brick laid, and then the brick to be laid is pressed into its place with a sliding motion, which forces the mortar to completely fill the joint. Having continued the inside and outside courses of brick to an angle or opening, the space between the brick should be filled with a bed of soft mortar, and the bricks pressed into this mortar with a downward slanting motion, so as to press the mortar up into the joints; this method of laying is called *shoving*. If the mortar is not too stiff, and is thrown into the space between the inner and outer courses of brick with some force, it will completely fill the upper part of the joints in the brickwork, which are not filled by the shoving process. A brick wall laid up in this way will be very strong and difficult to break down.

Another method of laying in the brick between the inside and outside courses in a wall is to spread a bed of mortar, and on this lay the dry brick. If the bricks are laid with open joints and thoroughly slushed up with mortar, it makes good work; but unless the workmen are carefully watched, the joints do not get filled with mortar, and the wall will not be as strong as when the bricks are *shoved*.

191. Some bricklayers lay the inside courses dry on a bed of mortar, as described in the previous paragraph, and

then fill all the joints full of very thin mortar. This is called *grouting*. No more mortar should be used than will fill all the joints. This method is not considered as good as those previously mentioned, because the mortar, being so thin, lacks cohesion, and does not bind the brick together as well as does stiffer and more tenacious mortar. Grouting should never be done in freezing weather; the mortar contains so much water that it freezes very readily and is then useless as a bond.

LAYING PRESSED BRICK.

192. Face brick are usually laid in mortar made of lime putty and very fine sand; often the mortar is stained with mineral pigments to match the color of the brick. The joints should not exceed $\frac{3}{16}$ of an inch in thickness, and, for very fine work, they are sometimes kept down to $\frac{1}{8}$ of an inch. The joints should be completely filled with mortar, and either finished at once or raked out for pointing. In very particular work, such as laying pressed and enameled brick, a straightedge is held under the joint and a jointer run along on top of it, thus making a perfectly straight joint. This is called *ruled* work. Many masons prefer using a trowel.

JOINTS IN BRICKWORK.

193. For inside walls that are to be plastered, the mortar projecting from the joints is merely cut off flush with the trowel. All outside walls and inside walls, where the bricks are left exposed, should have the joints *struck*, as shown in Fig. 74, (*a*), where *a* shows the mortar joint, and *b* the bricks in the wall. This *striking* the joint is done with the point of the trowel, which for the purpose is held obliquely. This method makes the best job for outside

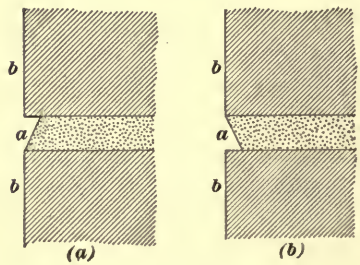


FIG. 74.

work, as the water will not lodge in the joint and soak into the mortar, as it will when the joint is struck as shown at (*b*), Fig. 74. The second form, however, is the easier one to make.

POINTING BRICKWORK.

194. Pointing consists in scraping out the old mortar in the outer joints, to the depth of at least half an inch, and filling them with fresh mortar, which is well worked in with a trowel. The object of pointing is to prevent access of moisture to the interior of the joint.

195. Both old and new work require, in many cases, to be pointed up again after laying; in new work, if attention has been paid to laying the brick properly with good ruled joints for face brick, and neatly struck joints in common brick, "pointing up" may not be necessary; in fact, if the brick have been laid according to the usual specifications, it would be entirely unnecessary. But when new work has been poorly laid, or where old work requires renovating, pointing is often resorted to. If it is intended to point up new work, the raking out should be done with a piece of hard wood while the work is in progress; old work will have to be raked with an iron raker. After raking, the joints should be well swept with a hard broom. In hot, dry weather the wall should be kept wet while the pointing is being done.

196. For mortar, Portland cement, mixed with about an equal quantity of clean, fine, sharp sand, is preferable, but if cement cannot be obtained, the best quality of ground lime may be used. This should be run through a very fine sieve, and mixed with fine sand before wetting, in the same way as cement. The whole quantity required for the job should be made up at one time, and kept moist, by placing in a damp place shaded from the sun and wind; and before it is used, it should be beaten into a proper state of consistency with a wooden or iron beater.

197. Tuck pointing is made by first filling the joint flush with brick-colored mortar, and then cutting a narrow groove along the middle of the joint; in this is laid a putty

paste, of the desired color, in such manner as to form a narrow ridge, the edges of which are trimmed so as to be parallel. This method gives the appearance of close joints, and disguises any irregularities in the work. In *bastard* tuck pointing, the ridge is wider, and is formed by a "jointer," having a V or C section, drawn along a straightedge.

198. **Bead** and **key** pointing differ from each other in that the first is made by a *jointer* having a semicircular section, producing a ridge of like shape; the second is formed by drawing along the joint a *key* having a circular form, pressing it in firmly, so as to compact the mortar.

BRICKLAYING IN EXTREME WEATHER.

199. Mortar, unless very thin, will not adhere to a dry, porous brick, because the brick robs the mortar of its moisture, and therefore prevents the proper setting. On this account, brick should never be laid dry, and in very hot, dry weather the bricks should be as wet as possible. When porous bricks are used this is of great importance in obtaining a strong wall.

200. Brickwork should never be laid in lime mortar when the thermometer is below 32 degrees, as freezing lime mortar unfits it for useful purposes, and work can never be done as economically in cold weather as at other times. Lime mortar is damaged when it alternately freezes and thaws. The sun shining on one side of the wall may cause the mortar to disintegrate, while that on the other side will be frozen. This may cause serious damage by causing the wall to buckle. In constructing large buildings in winter, if one-fifth cement is added to the lime mortar, it will not be damaged by freezing. It is necessary that the surface of the brick be clean and free from frost, snow, and ice, when they are laid, or the mortar will not adhere to them.

Sometimes salt is mixed with the mortar to prevent freezing, but it is undesirable, as it usually causes *efflorescence*, or the white deposit often seen spread over a wall.

Portland cement mortar and Portland cement and lime mortars are not affected by changes in temperature.

BOND IN BRICKWORK.

201. The proper construction of a brick wall involves many things besides the mere laying of one brick on top of another, with a bed of mortar between. The manner of laying or bedding the bricks, and the general method of doing the work having been considered, we will next take up the points in construction required to obtain a strong and durable wall, and the precautions to be observed to prevent settlements and cracks, and to adapt the work to the purposes for which it is intended.

202. In bricklaying, all corners and joints should be carefully plumbed, the courses of brickwork kept perfectly horizontal—which necessitates uniform mortar joints—and the wall surfaces, both exterior and interior, must be kept in perfect alinement. All these conditions may have been complied with, and yet the work may be imperfect; the merit of the brickwork must be judged by the thoroughness of the *bond* observed in every portion of the wall, both lengthwise and crosswise. This bond must be maintained by having every course perfectly horizontal, both longitudinally and transversely, as well as perfectly plumb. Aside from the quality and character of the material, the *bonding* of a wall contributes most of its strength.

203. **Bond,** in brickwork, is the arrangement of the bricks adopted for tying all parts of the wall together by means of the weight resting on the bricks, as well as by the adhesion of the mortar; and also for distributing the effects of the weight over an increased area.

204. When the bricks are placed lengthwise on the face of the wall, as at *a*, in Fig. 75, they are termed *stretchers;* when placed crosswise and their ends only exposed to view in the face of the wall, as at *b*, they are called *headers.* A *course* means the thickness of a brick and a mortar joint.

205. To obtain the best results in bonding throughout the mass of the wall, strict attention must be given to the location of *every* joint in the brickwork. On the faces

of the wall, the vertical joints in each course throughout the height should be kept perpendicular, or directly over those in the second course below. This is called *keeping the perpends*. Unless the closest attention is paid, the lap is ultimately lost through irregularity of the brick and mortar joints, and extra bats, or closers, are necessary. The joints across the top of the wall should also be kept in line, so that if the *perpends* are observed on one face of the wall, the other face will also work up correctly. Even when the wall is exposed on only one face, it is just as essential to have the joints on top of the wall kept in line, as otherwise its effective longitudinal bond will soon be lost, since at best the heading bond furnishes a lap of only 2 inches.

206. The importance of having the *bond* in brickwork preserved in the whole wall can be understood by reference

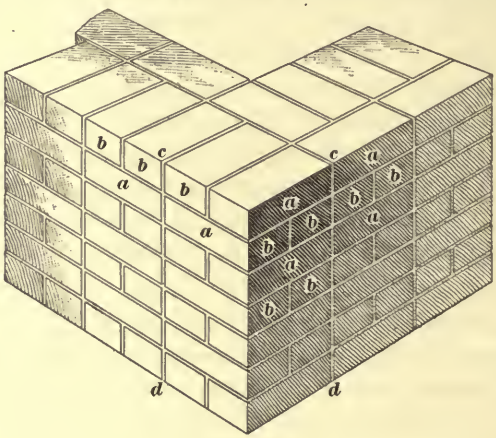


FIG. 75.

to Fig. 75, which represents a section of a wall consisting of alternate courses of stretchers and headers.

By the method of placing the brick as shown, no longitudinal bond exists, and the wall is simply a series of isolated piers which join each other at the vertical line *c–d*, and have no bond or union between them other than that obtained by the adhesion of the mortar.

This method manifestly lacks strength and efficiency. In

order, therefore, to overcome this constructive difficulty, and secure a continuous bond in the length of the wall, recourse is had to a different arrangement of the bricks and also to the use of blocks which vary in size from the ordinary brick.

207. These blocks are called *closers*, the term meaning that they perfectly finish or close the length of the courses which have been adjusted to obtain the bond. The vertical joint, which is shown at *c–d*, in Fig. 75, is avoided, and no two adjacent courses have joints which are immediately over each other. The closers are made by cutting the bricks with a smart blow with the edge of the steel trowel into such blocks as the situation requires. These are called *bats* and are designated according to the proportion which each bat bears to the whole brick. Pressed and enameled bricks are often cut with a cold chisel to get a more even fracture.

The different bats or closers used in brickwork are shown in Fig. 76; (*a*) represents a whole brick of the usual size,

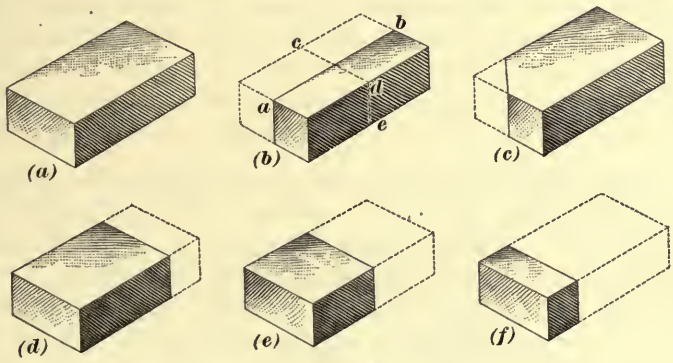


FIG. 76.

$8\frac{1}{4}$ in. $\times 4$ in. $\times 2\frac{1}{4}$ in. When the brick is cut longitudinally, as at (*b*), on line *a–b*, each half is called a *queen closer;* but as it is difficult to cut the full length in this manner, the usual mode is to first cut the brick on the line *c–d*, and then cut each half on the line *a–b*. When the brick is cut as at (*c*), it is called a *king closer*, and is a form well adapted for closers at door and window jambs, etc. When one-fourth of the whole length of the brick is cut off, as at (*d*), the remainder is called

a *three-quarter bat;* and in like manner the portion remaining, as at (*e*), is called a *half bat;* and at (*f*), a *quarter bat.*

208. In connection with the use of closers, whereby the lap is properly secured, there are several methods of placing the brick in the wall, each method having its own name to indicate the kind of bond used. A wall being considered as having the properties of a column, its bearing capacity will necessarily depend on the strength of its least dimension, which is its thickness, so that the bond which secures a thorough union of the constituent parts in this direction will always be the most desirable.

209. Heading Bond.—When all the courses present the end brick in the face of the wall, the wall will then be composed entirely of *headers;* this method, however, is only adapted for use in sharp-curved walls, as it possesses little longitudinal bond.

210. Stretching Bond.—When all the courses consist of *stretchers*, the wall formed should only be used for partitions that are but 4 inches in thickness; where the wall is thicker than this, the method cannot be followed, as there would be no transverse bond whatever.

211. English Bond.—Though not much used in this country, this is probably the best and strongest method of bricklaying. In English bond, the face of the wall shows header and stretcher courses alternately, as shown in Fig. 77. The longitudinal bond is obtained by the use of quarter-bat closers, marked *c*, and placed in alternate courses, as shown. This is without doubt the best and simplest method to follow in all work when strength is required, as by its use a complete and thorough transverse bond is procured. It will be observed that the heart of the wall consists entirely of heading bond, and that the joints of the heading course, as at *a*, are well bonded by the headers of the stretching course, as at *b*.

The English bond can also be accomplished by the use of the three-quarter bats, and many authorities prefer them to

quarter-bat closers, as by using three-quarter bats only one mortar joint is required in place of two.

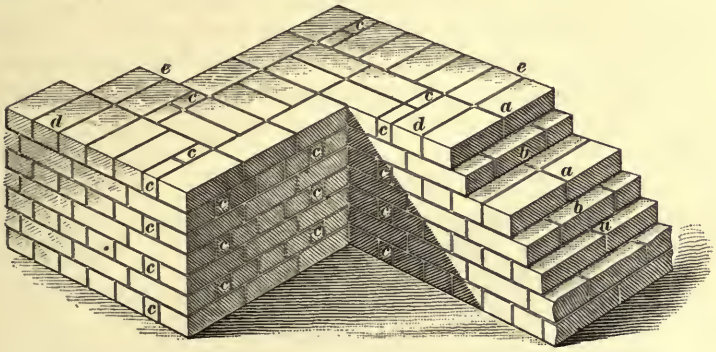


FIG. 77.

An objection frequently urged against the appearance of the English bond on the face of the wall, is the recurrence of so many headers, which give the work the appearance of being constructed of so many tile-like blocks. The use of diminutive blocks of either brick or stone, in heavy walls, always tends to reduce the *apparent* strength of the structure, and it loses much of the effect of *permanence*, a very effective factor in good design.

212. The Flemish bond is used to overcome, in a measure, this belittling effect, and is one where only two-

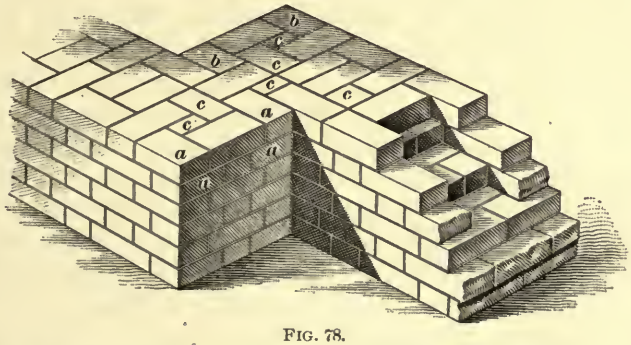


FIG. 78.

thirds of the number of headers that occur in English bond are exposed, and each course is composed of a header and

stretcher alternately. The method of laying brick in Flemish bond is shown in Fig. 78. The lap in this case is obtained by the use of three-quarter bats, both at the external and internal angles of the wall, as shown at *a* on the external, and at *b* on the internal angles. In Flemish bond the closers occur in the heart of the wall, just as was shown in English bond; these are quarter, half, and three-quarter bats, as shown at *c*.

It will be seen by referring to Fig. 78, that owing to the headers and stretchers being placed on the inner side of the wall immediately opposite those on the outer face, both faces will appear exactly alike when thus arranged; the wall is then said to be built in *double Flemish bond.*

By carefully examining Fig. 78, it will be seen that only one-half of the body of the 4-inch thickness is bonded to the adjacent thickness; in other words, the upper bed of each face stretcher is only bound to the inner thickness by means of the width of one header; in this respect, the strength of wall is sacrificed for the sake of appearance. A continuous vertical strip 2 inches wide occurs on each side of the face headers, which has no bond other than that of the adhesion of the mortar. To obviate this defect, the outer face is sometimes built in Flemish bond and the inner face in English bond.

213. Garden or Running Bond.—The bond most generally used in this country is shown in Fig. 79. This method, which enables the bricklayer to build a larger amount of wall in a given time than can be accomplished by the use of either the English or Flemish bond, is sometimes called **American bond.** It consists in laying from five to seven courses in height as stretchers, bonding with a row of headers at regular intervals. The longitudinal lap is secured by closers *c*, *c*; the heading course in the heart of the wall is shown at *a*, *a*, being placed immediately over the heading course *b*, *b* exposed on the face. This is known as *garden* or *running bond.* Its principal defect is that the wall is practically composed of a series of 4-inch slices from

12½ to 17½ inches in height, which have no transverse bond other than the mortar, under ordinary circumstances. It fulfils the requirements, however, if every joint throughout the body of the wall is well filled with good mortar, the vertical joints being well rammed with the edge of the trowel.

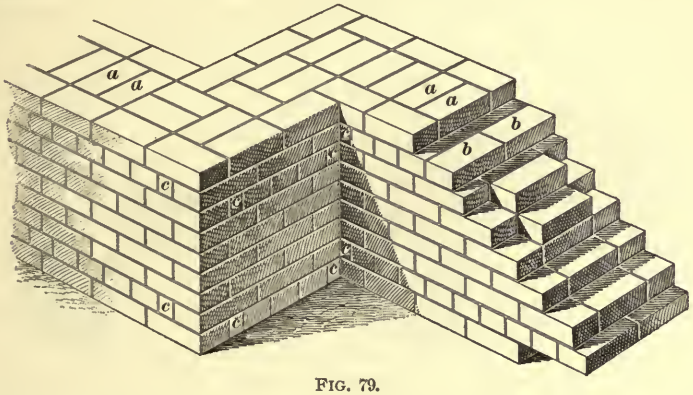


FIG. 79.

The New York building law requires that every sixth course shall be a heading course; that is, that five courses of stretchers shall come between two courses of headers, as shown on Fig. 79.

For factory and warehouse purposes, where heavy weights come on the wall, it is better to have every fourth course a header course, thus giving three courses of stretchers between the header courses.

214. Bonding Face Brick.—When face or pressed brick are used for the exterior facing of a brick wall, it detracts from the uniform appearance of the brickwork if the bonding headers appear on the exterior face of the wall. There are several ways of avoiding this difficulty; either by cutting the face brick and the rough brick, or by using steel wire ties to bond the brick together. If no tie or bond were used, the whole 4 inches of brickwork on the face of the wall would have no other connection with the rest of the brick than that given by the adhesion of the mortar, and indeed might be pushed away bodily from the rough brick.

215. Fig. 80 shows a 12-inch wall with the face brick bonded to the common brick by what is known as *diagonal*, or *herring-bone*, *bond*. At *a* is shown the front brick cut at the angles; at *b*, the bonding brick laid diagonally; at *c*, the different shaped bats laid to form the closers of the bond brick; and at *d*, the inside course of stretchers. It is customary to lay an inside course of headers immediately over the course shown in the figure.

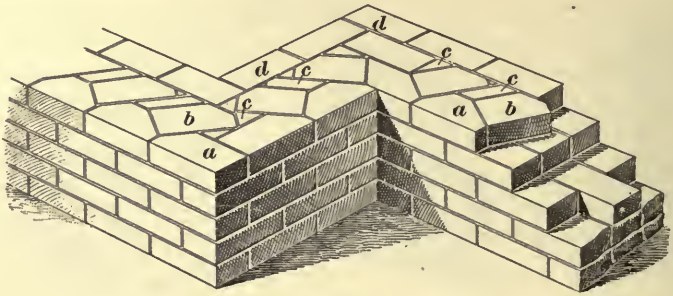


FIG. 80.

The New York building laws require that "where walls are faced with brick in running bond, every sixth course shall be bonded into the backing by cutting the corners of the face brick, and putting in diagonal headers behind (as shown in Fig. 80), or by splitting the face brick in half and backing the same with a continuous row of headers."

This last method is shown on Fig. 81. The face brick,

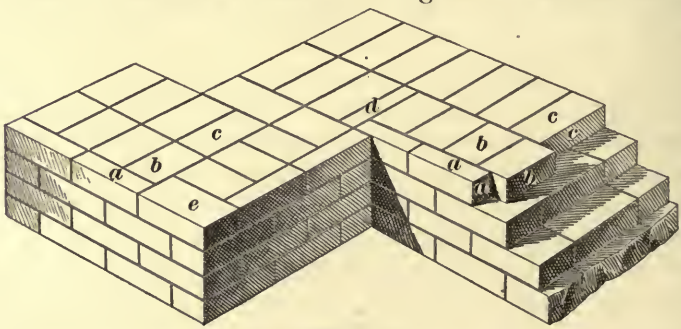


FIG. 81.

cut lengthwise, are shown at *a*. At *b*, are the three-quarter bats bonding in back of the face brick. The whole brick *c*

bonds on the inside of the wall *d*, the closer closing up the angle, and *e* is the whole face brick on the corner of the wall.

216. Fig. 82 shows the method of bonding in face brick with steel or galvanized iron wire. These wire bonders are

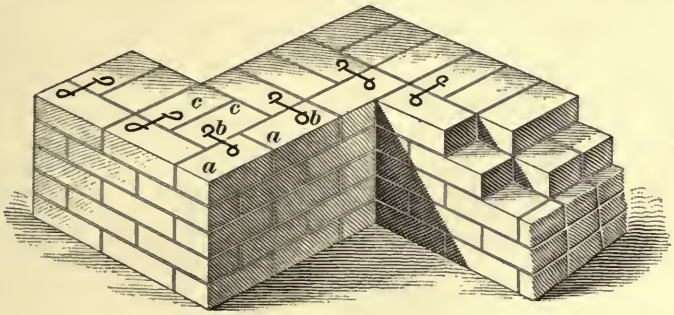


FIG. 82.

twisted at the ends, as shown, to get a better bond, and are laid in every sixth course of brick. The principal objection to the use of steel or iron bonders is the danger of rust, although by the time their efficiency has been destroyed by the action of rust, the mortar used should have hardened sufficiently to keep the face brick in place.

A still more modern method of tying front brick to the common brick in the rear of the wall, is by use of perforated

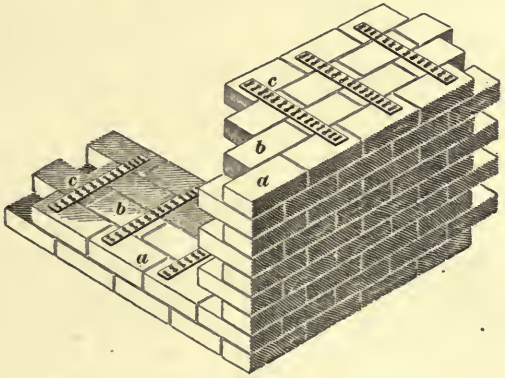


FIG. 83.

steel ties from $\frac{3}{32}$ to $\frac{1}{8}$ of an inch thick, and having about half the metal punched out. The brick may be brought down to

a very close joint, and the clinching spaces make a very firm and satisfactory binder. Fig. 83 shows the application of these bonding strips. Here *a* is the pressed brick facing *b*, the common brick in the rear of the wall, and *c*, the perforated steel ties bonding the pressed brick back to the common brick.

The same tie can be used for tying new work to old where walls require lining up to increase their strength. The tie is bent near the middle, as shown at *a* in Fig. 84, and nailed to the old wall with pointed wrought-iron nails, shown at *b*, having large flat heads made for the purpose and of sufficient size to make a firm connection for the new courses *c*. This method avoids the cutting in the old wall *d* to get in cross-headers, which, at best, must hold very imperfectly after the inevitable shrinkage which comes to all new brickwork.

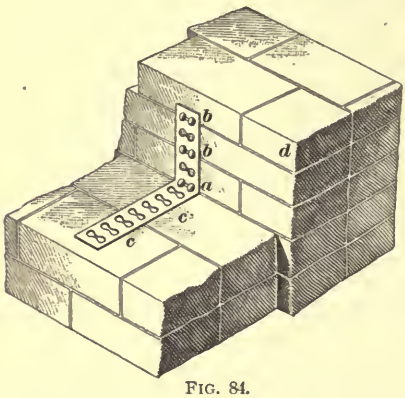


FIG. 84.

HOLLOW WALLS.

217. Even a solid brick wall readily absorbs moisture and also transmits heat and cold. A driving rainstorm of several days duration will often penetrate a 12 or 16 inch wall, and so dampen the brick as to affect the wall paper or plastering, or spoil fresco decorations. The moisture from the brickwork prevents the mortar, if of lime, from becoming hard, and may communicate dampness to the woodwork, causing rot. Damp walls in a building necessitate the consumption of much more fuel to warm the rooms than when the walls are dry, because the moisture must be evaporated before the temperature of the rooms can be raised.

To overcome this difficulty, several methods are resorted to; the one most in use consists in furring the outside brick with furring strips (see *Carpentry*), and lath and plaster on

these. The danger from fire spreading through these strips, especially in hospitals, schoolhouses, and isolated private residences, has caused many excellent authorities to recommend the use of hollow brick walls.

218. Hollow walls are intended to keep moisture from passing through, and, on account of the air space provided, keep the building much cooler in summer, and warmer in winter. Difficulties in construction are met with, however, that largely offset their advantages, so that hollow walls are seldom used in this country. There is no doubt but that their use might be much extended, with good results, more especially for isolated buildings. The objections to hollow walls are that more ground area is required, and the cost of construction is increased.

The air space should be continuous throughout the wall in order to obtain the full benefit of the space. It is also well to have the bond, or connection between the two parts of the wall, of such shape and material, that any moisture penetrating the outer portion of the wall cannot penetrate the inner part. Brick bonding neutralizes some of the benefit gained, by permitting the passage of moisture through the wall where it is bonded.

It is practically impossible when a wall is penetrated by openings, to provide a continuous air space, though it may be closely approximated.

219. Fig. 85 shows one form of hollow wall with an 8-inch outer wall *a*; a 2-inch air space *b*, and a 4-inch inner

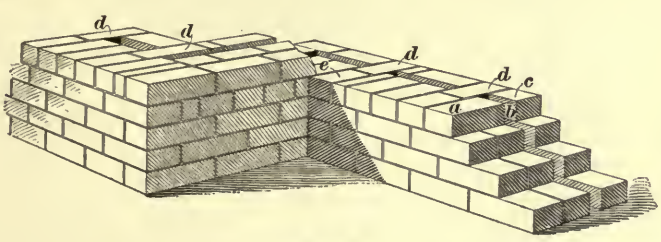


FIG. 85.

wall *c*. This wall is bonded every sixth course in height, and every 8 inches in length, as shown at *d*. The header

bricks *e* that join the bond *d*, are three-quarter bats, and the bond bricks have 2 inches bearing on the front wall.

220. Fig. 86 shows a 10-inch wall that has a 4-inch wall *a*; then the 2-inch air space *b*, and the inner 4-inch wall *c*. The bond brick are cut at an angle as shown at *d*, and where they

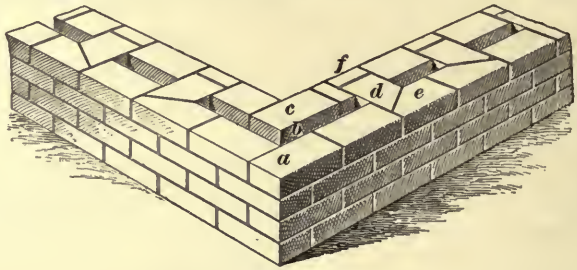


FIG. 86.

miter in the front wall the front brick are also cut, as at *e*. The 2-inch space left in the rear wall *c*, where the bond brick occurs is filled with a closer *f*; this closer is a quarter bat.

221. A method of bonding which retains the full benefit of the air space, is by means of metal ties, as shown in Fig. 87. Here *a* is the 4-inch outer wall; *b*, the air space; *c*, the inner

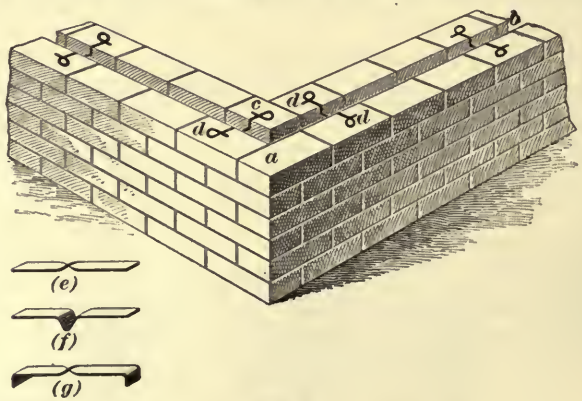


FIG. 87.

4-inch wall; and *d*, *d*, the metal ties. The ties are known as Morse ties, and are made of steel wire galvanized, and from 7 to 16 inches long. Other forms of ties are shown at (*e*), (*f*), and (*g*); these are made of iron and can be procured of any

blacksmith. The form shown at (*g*) is probably the best, as the lugs on the end of the tie fit between the courses of brick. All metal ties should be dipped in hot asphalt to keep them from rusting.

When any of the metal ties *d*, (*e*), or (*f*) are used, they should be spaced every 24 inches in every fourth course. The tie (*g*), being stronger, need be used in every eighth course only.

222. Fig. 88 shows the construction of a hollow wall around a window opening; *a* shows the outside 4-inch wall; *b*, the 2-inch air space; *c*, *c*, the 12-inch cellar and the 8-inch first-story inner walls; *d* is the bonding brick alongside the window opening; *e*, the window sill; *f*, the window lintel; *g*, the brick arch over the window opening; *h*, the asphalt covering on top of the arch, to prevent any moisture from passing through the hollow space into the window opening; *j*, the steel wire bonders that bond the inner and outer walls together; *k*, the second-story floor-beams; *l*, the first-story beams; and *m*, a pipe to drain any moisture that might collect in the hollow wall.

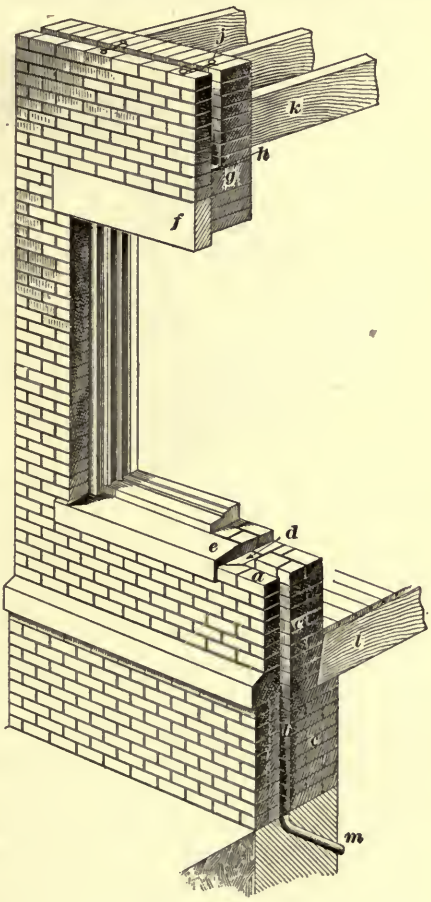


FIG. 88.

HOLLOW WALLS WITH BRICK WITHE BONDS.

223. There is also a method of constructing hollow brick walls with a 4-inch outer and inner facing, connected by solid brick **withes** (as these short cross brick partitions are called). The air space may be either 4, 8, or 12 inches, according to the height and character of the building. Fig. 89 shows an example of this mode of construction, being a hollow wall 20 inches thick and 12 inches between inside of brickwork. At *a* is shown the outer brick wall, while *b* shows the inner

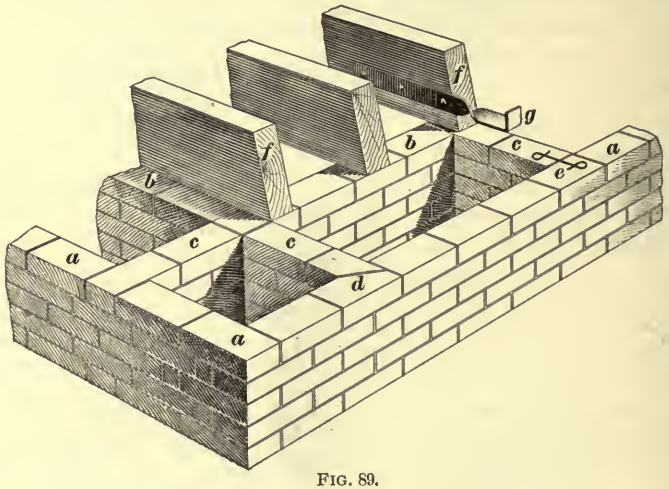


FIG. 89.

wall; the *withes*, or connecting walls, are shown at *c*, *c*. The bond is shown in two different ways; at *d*, the bricks are cut as shown on Fig. 86, and at *e*, the bond is made by wire bonders as shown in Fig. 82; *f* shows the manner of placing the floorbeams on the inner wall, and *g*, a $2'' \times \frac{1}{4}'' \times 20''$ anchor, turned up at the end, to bond the floorbeam into the joint of the cross-wall or withe.

If such a wall is made of good quality of brick, such as are made in most of the New England and Middle states, and with *perfect* workmanship, it ought to have sufficient strength for an ordinary three or four story building, and would certainly conduct less heat and moisture from and into a building than a solid wall of one-half more brick. When the

brick and workmanship are both equally poor—as is found in some parts of the country—walls built in this way should not be used in the construction of any buildings higher than two stories.

VENEERED WALLS.

224. In some sections of the country, dwellings and other buildings that are often three or four stories high, are built with the inner walls of frame construction, and this frame is *veneered* on the outside with a 4-inch facing of brick. This, of course, is to a certain extent a sham, as buildings constructed in this way have the same appearance, both externally and internally, as though constructed entirely of brick. Where lumber is cheap, and brick scarce and expensive, this method of construction, however, possesses some advantages.

A brick-veneered house costs less than a house constructed entirely of brick; and the air space prevents moisture entering, making the house warmer in winter and cooler in summer. About the only real advantage that a brick-veneered house has over a well built frame building, other than that above mentioned, is that the brick veneer offers some protection from fire in adjoining buildings, thus reducing, somewhat, insurance rates. A fire occurring inside would probably destroy a brick-veneered building as rapidly as though the frame were covered with wooden siding or shingles.

225. In planning a brick-veneered building, it must be remembered that the walls are 5 inches thicker (4 inches of veneer and 1 inch of air space) than the walls of a frame building, and the stone or brick foundations ought to project far enough beyond the frame to support the veneer.

When the walls are laid out on the floor plans, allow 6 inches from the *face* of the studding to the face of the brick-veneer wall. This will leave a 1-inch air space between the brick and the diagonal sheathing after the latter is put on, and also avoids cutting away the bricks, should the

framing be a little too full. In many cases, a 2-inch V-shaped drain is built under the air space in the foundation wall to collect any moisture that may come through the veneer.

Care must be taken to construct the frame in the best manner, and the timber used in framing should be extra heavy, for it must be borne in mind, that the brick veneer carries absolutely no part of the inside construction of the building, and in fact has to be tied to the wood framing for support. After the frame is up it should be sheathed diagonally and then covered with tarred felt. All the framing timber, particularly the sills and girths, should be as dry as possible, and the frame must be perfectly plumb and straight; if not, the brick veneer will not lay up properly.

226. Pressed, or face, brick are usually tied to the diagonal sheathing with metal ties. The wire tie, known as the Morse tie, shown at (*a*) in Fig. 90, is most generally used, although a tie made of No. 16 iron, 1¼ inches wide, with the end turned under, as shown at (*b*), Fig. 90, gives satisfactory results. The ties should be placed on every other brick in every fifth course of brickwork.

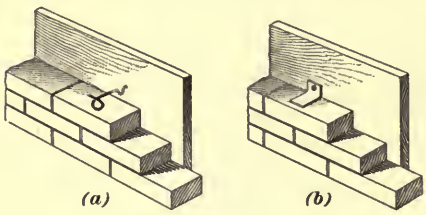


FIG. 90.

Ventilation is usually accomplished by means of a 2-inch drain tile at the bottom, as shown on Fig. 91 at *o*.

The brickwork usually finishes under the eaves or gables. If there should be a flat roof on the building, with parapet walls, the parapet should be coped with tin, copper, or galvanized iron, and tinned on the back down to the flashing.

227. Fig. 91 shows a section through part of the foundation of a veneered building, and the principal features of its construction. At *a* is shown the stone foundation wall, projecting 5 inches beyond the diagonal sheathing *b*; the $6'' \times 4''$ sill is shown at *c*; the $3'' \times 10''$ floor joist, at *d*; and the air space between the brickwork and the sheathing, at *e*.

The 4-inch brick-veneer wall is shown at *f*, and the Morse wire tie, at *g*; the stone window sill is shown at *h*; the

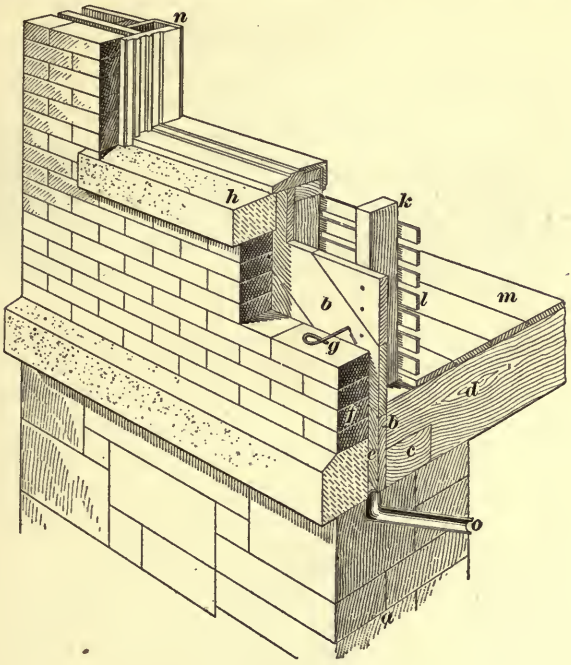


FIG. 91.

$2'' \times 4''$ studding, at *k*; the lathing, at *l*; the flooring, at *m*; and the window frame, at *n*; while *o* shows the 2-inch ventilating drain pipe at the bottom of the 1-inch air space.

TERRA-COTTA FURRING.

228. A form of construction much used, especially in fireproof buildings, is by means of terra-cotta blocks, as shown in Fig. 92, or hollow brick, as given in Fig. 93. Fig. 92 shows the hollow blocks, which are usually about 2 feet by 20 inches, so they can be fastened to every sixth course of brickwork by wire ties, as shown at *b*, or bent hoop iron, as at *c*. The wall, as shown at *d* in Fig. 93, is 16 inches, or two bricks, thick, and, as the terra-cotta blocks are 4 inches thick, the total thickness of the wall is 20 inches.

When hollow brick are used for inside furring of outside walls, they are laid as shown in Fig. 93. As the hollow

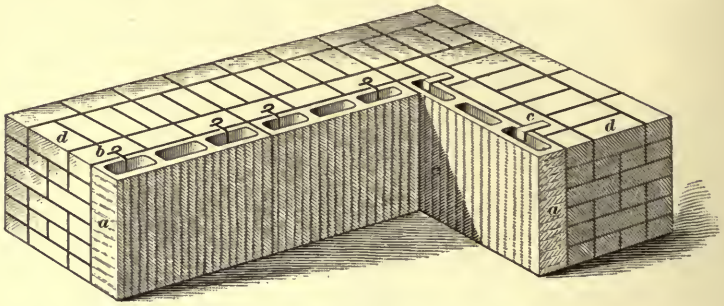


FIG. 92.

brick are made just the size of ordinary common brick, they can be bonded into the solid brick wall with header courses, just as the common brick are bonded. At *a*, Fig. 93, appear the header courses of hollow brick, and at *b*, the

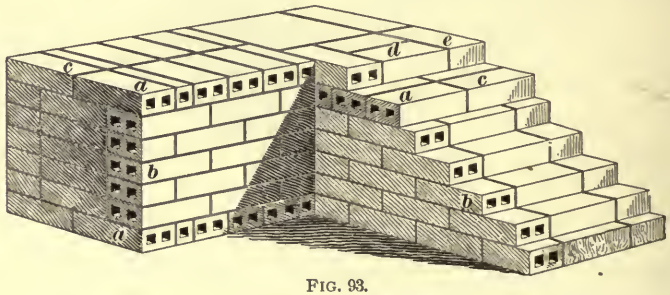


FIG. 93.

stretcher courses; *c* gives a view of the header courses of common or solid brick; *d*, the inner brick of the wall between the stretcher courses; and *e*, the outside stretcher course of the wall.

CHIMNEYS.

229. In planning and building brick chimneys, the chief things to be considered are the height of the chimney, and the number, size, and arrangement of the flues.

To make the chimney "draw properly," a separate flue should be provided, extending from each fireplace to the top

of the chimney. The furnace in the cellar and the kitchen range may connect with the same flue, and, as the range fire heats the flue and is above the furnace, the furnace draft is often better when connected with the range flue.

For ordinary stoves, and where a small furnace is used, the flues may be the usual size, 8 in. × 8 in., or the space taken by two bricks. If the furnace is a large one, it is better to make the flue 8 in. × 12 in., and the same size should be used, when possible, for fireplaces having large open grates.

Sometimes smoke flues are made only 4 inches wide. But they soon become choked with soot and are difficult to clean. It is well not to make a chimney flue less than 8 inches.

Smoke flues should always be lined with some fireproof material; in fact, the building laws of large cities provide for this. The lining is usually of fireclay, tile, or else of galvanized-iron pipe. If the pipe used is round, the space between it and the walls of the chimneys may be utilized for ventilating the rooms through which the chimneys pass, by putting ventilators in the wall of the flue. The outer walls of chimney flues should be 8 inches thick if flue linings are not used, to prevent the smoke becoming chilled too rapidly.

230. Insufficient height causes more smoky and badly drawing chimneys than any other cause. Chimney flues should, whenever possible, extend above the highest point of the building or those adjoining it. If this is not done, eddies may be formed by the wind passing over the higher parts of the roof and causing a downward draft in the chimney flues, under which circumstances they are sure to smoke. This may be obviated, when the chimney is not carried high enough, by using a hood having two open sides. Hoods are unsightly in their appearance, and their use should be avoided when possible.

231. Chimneys were formerly *pargeted*, as it was called; that is, the partitions, or *withes*, of a chimney were plastered with a mixture of cow manure and lime mortar. This is now seldom or never used; if it is deemed necessary to parget the inside of a chimney, Portland cement makes the

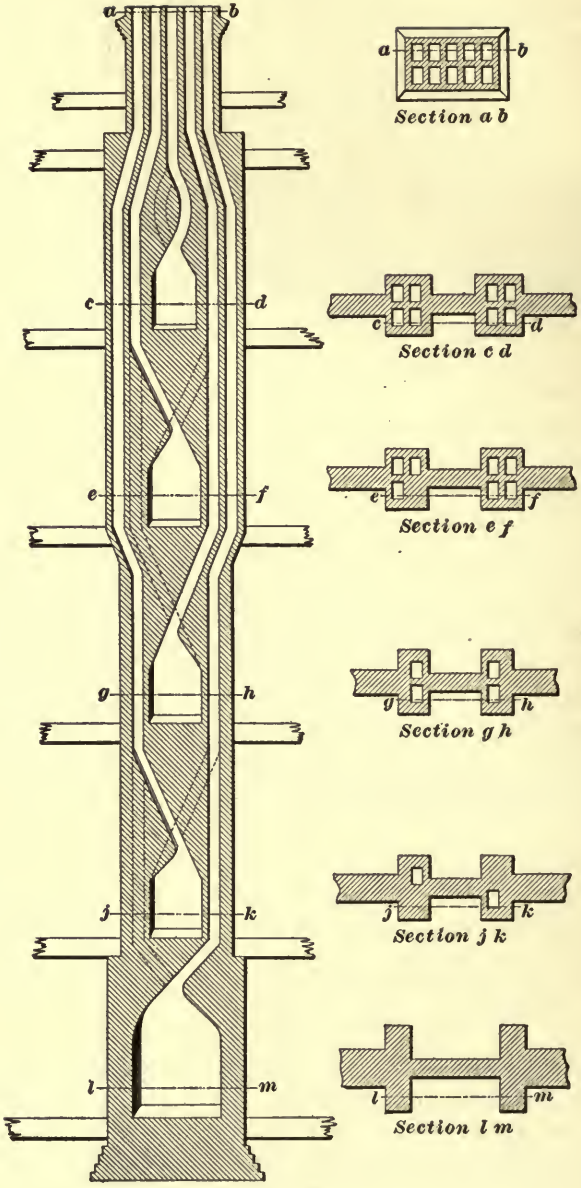

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FIG. 94.

best material to use. This is not affected by heat and will prevent sparks or air passing through the cracks, and also increases the draft. When an iron or fireclay tile pipe is used, pargeting is unnecessary.

232. During the building of a chimney, pieces of brick and lumps of mortar will drop down in the flue; therefore, a hole should be left at the bottom, with a board put on a slant to catch the falling mortar. After the chimney is topped out, the board and mortar can be removed and the hole bricked up.

Where bends occur in the flue, openings should be left in the wall to clean out any pieces of brick or mortar that may have lodged there.

233. Fig. 94 shows vertical and horizontal sections of a double chimney running through five stories, with fireplaces on each floor. The section *a–b* shows the way the chimney is "topped out" and the arrangement of the flues. The fireplaces on the different stories, and the run of the flues are shown at *c–d*, *e–f*, *g–h*, and *j–k*; *l–m* shows the sectional views of the range chimney in the kitchen. The flues are shown as 8 in. × 12 in., as affording a better draft than 8″ × 8″ flues for open fireplaces. If stoves are to be used, or if the space is valuable, 8″ × 8″ flues may be substituted.

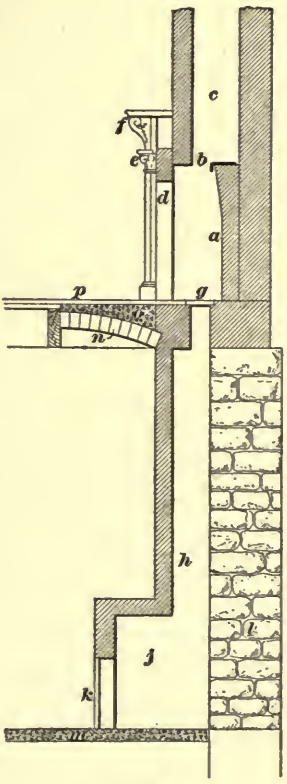


FIG. 95.

FIREPLACES.

234. Fig. 95 shows a section through a fireplace with an ash flue leading down to the cellar. The back of the fireplace is often constructed of firebrick and

brought forward as shown at *a*, and an iron damper arranged as shown at *b*, to slide back and forth, to regulate the draft. At *c* is shown the chimney flue, in this case made 8 in. × 12 in.; *d* is the facing of the fireplace, which should project 4 inches beyond the outside brickwork of the chimney breast, so as to bring the grate forward into the room, the height of this opening or facing above the hearth being usually 30 inches; *e* shows the tile border to the fireplace opening, and *f*, the mantelpiece. The bottom of the fireplace has an opening in it, covered with an iron cover *g*, to let the ashes down through the ash shaft *h*, into the ash-pit in the cellar, shown at *j*. This ash-pit has an iron door *k* for the removal of the ashes. The stone foundation wall of the cellar shows at *l*, and *m* is the concrete bottom. The hearth is generally supported by a trimmer arch *n*, springing from the chimney, and resting against a header framed in the floor. The space above the arch *o* is filled with concrete, and leveled off to receive the tile or brick hearth *p*.

CONSTRUCTION DETAILS.

ANCHORING THE WALLS.

235. This is very often specified under carpenter work, and is by some considered as belonging more especially to that trade, but it is also a matter of concern to the mason.

It is extremely important that the joists should be securely anchored to the walls, as the danger of the walls being thrown outwards, either from settlement of the foundations, or from pressure exerted against the inside of the wall, is sometimes very great, and should never be overlooked by the architect or contractor. Many walls might have been saved from falling and having to be rebuilt, had they been properly anchored. A high wind coming up during the progress of the work, and while the mortar is green, has often blown down walls that would have remained intact had proper attention been paid to the anchoring.

236. The floors should be tied to the brick walls at least once in every 6 feet, by means of iron anchors spiked to the floor joists and built into the wall. Sometimes a box anchor or floor hanger is used.

Fig. 96 shows the four forms of iron anchors that are generally used. The one shown at (*a*) is made of $\frac{1}{4}'' \times 1\frac{3}{4}''$ iron about 2 feet long; the end built in the wall is made of a $9'' \times \frac{5}{8}''$ rod with the end of the anchor drawn around it.

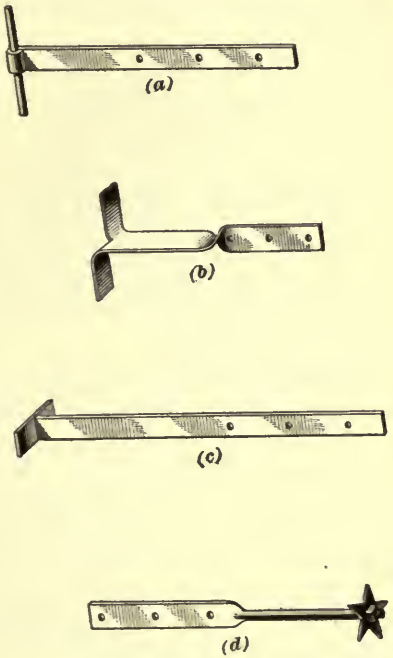


FIG. 96.

The anchor (*b*) is made of $2'' \times \frac{3}{16}''$ iron, 2 feet long; the end that goes in the wall is cut as shown, and about 4 inches is turned up at right angles to the end of the anchor; the other end is twisted around so that it can be nailed to the side of the joists, as shown in Fig. 97.

When the brick wall is on the side or rear, and the appearance of the wall is not considered, it is better to let the anchor run clear through the wall. The anchor shown at (*c*) in Fig. 96 is used with this method of anchoring. It is made of $1\frac{3}{4}'' \times \frac{1}{4}''$ iron, 2 feet 6 inches long, and has a plate of $2'' \times 4'' \times \frac{1}{4}''$ iron, doweled in on the outer end. An anchor of this kind gets a better hold on the wall than when it stops in the middle of the wall. It may also be used for building into the middle of the wall, the same as (*a*) and (*b*).

When an especially strong anchor is required, the form shown at (*d*), Fig. 96, is considered the best. This style of anchor is made by flattening out a $\frac{3}{4}$-inch bolt so as to make

a $2'' \times \frac{1}{4}''$ portion to spike to the joist, and is provided with a 5-inch cast-iron star washer. A nut is placed on the outer side of the washer so that the anchor may be tightened up if necessary after the walls are built.

237. Fig. 97 shows the method of anchoring the joists to the walls; *a* is the brick wall; *b*, the wooden joist; and *c*, the iron anchor. The anchors should always be spiked to the side of the joist or girder near the bottom as shown. If the anchor is placed near the top of the joist, the destructive effect on the wall, should the joist fall, will be materially increased.

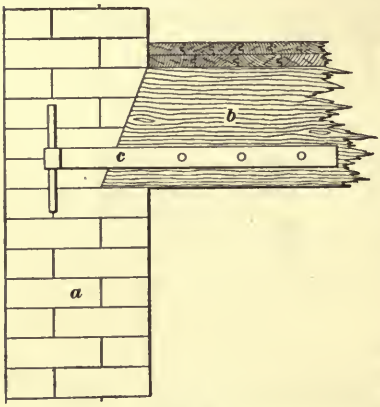


FIG. 97.

Fig. 98 shows the method of anchoring the joist to the walls where the joist and the walls run parallel. The anchor is let into the floor joists, as shown at *a*, and it should be long enough to run over two or three joists, in order to give proper stiffness. The form of anchor shown at (*c*), in Fig. 96, is the best for

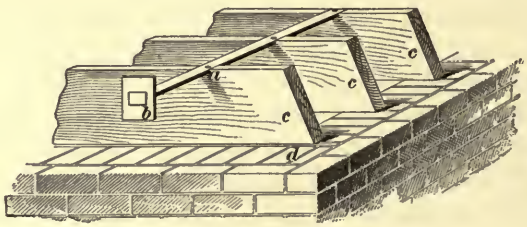


FIG. 98.

this purpose, and the end plate *b* can either come outside the wall or be built into the brickwork. At *c*, Fig. 98, is shown the floor joist, and *d* shows the top of the 12-inch brick wall.

CORBELING FOR FLOOR JOISTS.

238. Architects sometimes specify a ledge to support the floor joists, by using a continuous brick corbel of three or more courses. This mode of construction is shown in Fig. 99. At *a* is the 4-inch brick corbel, of three courses of brick; *b*, *b* shows the wooden floor joists; *c* is a strip of plank placed between the floor joists to nail the rough flooring to; *d* is the rough floor, and *e* the tongued-and-grooved flooring; *f* is the 1″×2″ furring on the wall, and *g* the lath and plaster over the furring strips. Corbeling out for the floor joists

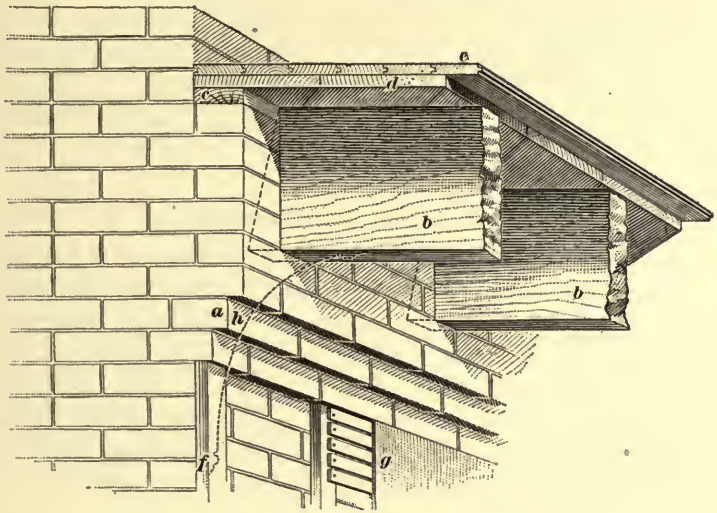


FIG. 99.

has several advantages, one being that, in case of fire, the corbels act as a fire-stop, largely preventing the spread of the flames from story to story; and, in case the floor joists fall, they are inserted such a short distance in the wall that they will not have so much tendency to pull the wall over as if anchored. The wall is also much stronger when corbeled out, for whenever timbers extend into a wall, they lessen the section, or bearing area, by just the amount of space taken up by the ends of the floor joists, and in partition and party walls this is very considerable.

When walls are corbeled out in this way, a plaster or wooden cornice is required, to give a proper finish to the junction of wall and ceiling, and to form the angles of the rooms. This cornice is shown on the dotted line at *h*, Fig. 99.

All corbeling for floor joists should be executed in good hard brick; no salmon or soft brick should be allowed in the construction, for, as much of the weight of the floor joists and floors bears on the corbel, any structural weakness might cause serious results.

239. In Chicago, the building law provides that all walls of warehouses, 16 inches or less in thickness, and all walls of dwellings, 12 inches or less in thickness, shall have ledges 4 inches wide, corbeled out to support the floor joists, and in all cases when the ledges are built, they are to be carried to the top of the joists, as shown in Fig. 99.

CARRYING UP WALLS EVENLY.

240. It is very important that the walls of a building should be carried up as evenly as possible, no wall being built more than 3 feet above the rest unless separated by an opening. If one part of a wall is built up ahead of another, unequal settlement is produced. The joints in the brickwork of the higher part will have set before the remainder has been added, consequently the work laid last is very likely to settle away from the other. This not only weakens the wall, but also mars its appearance.

If it is absolutely necessary to carry up one part of a wall higher than the rest, the end of the high part should be stepped, or *racked* back, and not run up vertically, with only toothings left to connect it with the rest of the work.

BONDING WALLS AT ANGLES.

241. A very important feature in brick construction is that both the front and rear walls should be securely bonded and anchored to the side, party, or partition walls. If possible, all the walls should be carried up together, but delays

in obtaining the iron, stone, etc. often make it necessary to carry up the side and partition walls first.

When this is the case, the end of the side walls should be built with toothings, as shown in Fig. 100, each one being eight or nine courses high, as at *a*, *a*, into which the backing of the front wall should be bonded.

In order to unite the two walls more firmly together, anchors made of $\frac{3}{8}'' \times 2''$ wrought iron, with one end turned up 2 inches, and the other turned around a $\frac{5}{8}$-inch bar, should be built into the side wall about every 4 feet in height, as shown at *b*. These anchors should be long enough to extend at least 16 inches, or the depth of two bricks laid the long way, into the side wall, and the center of the $\frac{5}{8}$-inch rod should be about 8 inches from the back of the front wall.

The building laws of nearly all the large cities require that all intersecting brick walls shall be tied together in this way.

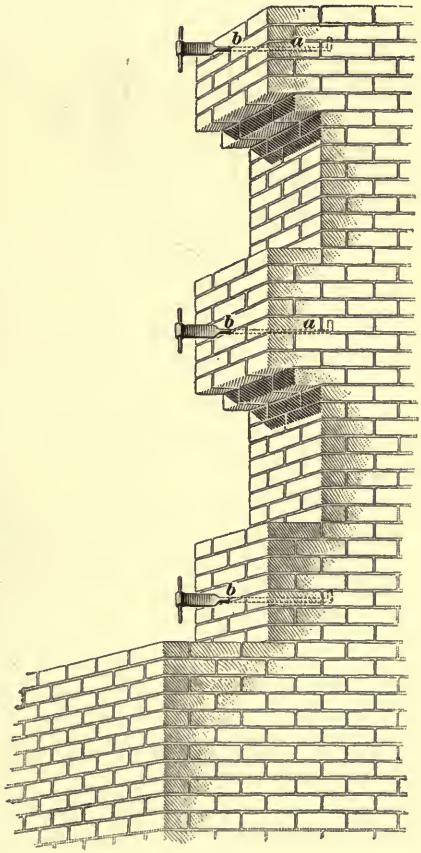


FIG. 100.

OPENINGS IN WALLS.

242. When a brick wall contains door and window openings, their location and relative position should be very carefully considered, not only with regard to convenience

and symmetry, but also with regard to their effect on the strength of the wall. When walls are broken frequently by windows and other openings, cracks are more likely to occur

FIG. 101.

than when the wall is plain and unbroken. This is owing to the unequal pressure on the mortar joints. If walls are well bonded and anchored, the danger of cracks may be reduced to a minimum.

243. The combined width of openings, in any bearing wall carrying the ends of floorbeams, should not be more than one-third the total length of the wall, unless the thickness of the wall between the windows is increased by the use of piers, pilasters, or buttresses. All window openings should be placed directly over each other in the different stories, when possible.

The placing of windows under a pier, or directly over a narrow mullion, should always be avoided unless absolutely necessary. The effect of this is shown in Fig. 101. At *a* is shown a window opening under a pier; the combined effects of the load of brickwork and the settlement of the joints have caused the sills of the upper windows and the lintel of the lower window to crack, and the cracks have extended through the brickwork. At *b*, the weight of the brickwork, pressing on each side of the wall over the window mullion, has concentrated the weight on the center of the lintel *c* and mullion *d*, and has caused them both to crack.

244. If it is found absolutely necessary to place windows in the positions shown in Fig. 101, steel beams should be placed over the windows *b*, to carry the load and prevent cracking of the lintels and sills. In fact, all windows in exterior walls, especially if they are in bearing walls, should have either relieving arches, cast-iron lintels, or iron or steel **I** beams behind the stone lintel, or face arches. When the width of the window opening is less than 6 feet, it is usual to put in relieving arches. Steel or iron **I** beams, or cast-iron lintels, preferably the former, are used for greater widths. If the top of a window or door opening in a bearing wall comes within 12 inches of the bottom of the floor joists over the opening, relieving arches should not be used, especially in warehouses or where there are heavy loads on the floor.

245. The best lintels for use in unplastered brick partitions in warehouses are cast iron, as shown in Fig. 102, where (*a*) shows the elevation, and (*b*) the section of the lintel. The line *a*–*c* is the bottom of the lintel, and the dotted

line *b* the top of the arched web. The advantage in using this form of lintel is, that it gives a smooth surface to the

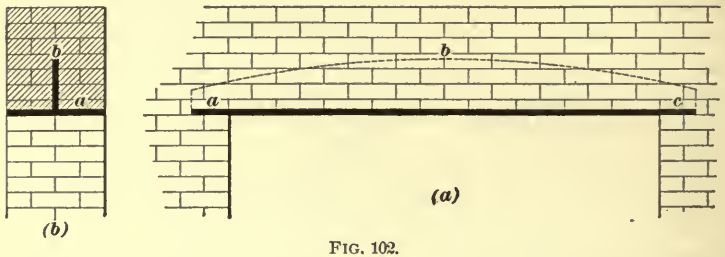


FIG. 102.

soffit, or under side of the arch, and shows only a narrow strip of metal on the face of the wall.

JOINING NEW WALLS TO OLD.

246. In joining a new wall to an old, when the walls come at right angles, the new work should not be toothed or bonded into the old work, unless the new work is laid up in cement mortar. All mason work built with lime mortar will settle somewhat, owing to a slight compression of the mortar joints, and this settlement is apt to cause a crack where old and new work is bonded together. In place of toothing, or bonding, a groove should be cut perpendicularly in the old wall, usually the width of a brick, to make a joint; this is called a "slip joint."

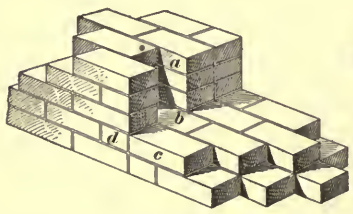


FIG. 103.

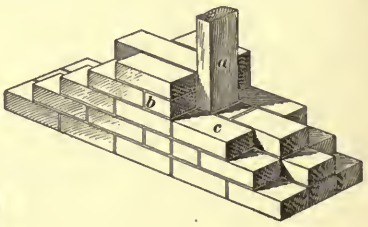


FIG. 104.

This method of bonding is shown in Fig. 103. At *a* is seen the groove or chase cut, where the new wall is to enter in the old wall; *c* is the new wall, and *d* the old wall.

In cheap construction, where new work is bonded into old, the method most commonly used is to nail a piece of $2'' \times 4''$ timber against the wall, as shown in Fig. 104, where *a* shows the $2'' \times 4''$ timber spiked to the old wall, and entering the center of the new wall; at *b* is shown the old, and at *c* the new wall.

PARTY WALLS.

247. A party wall is the wall separating two adjoining buildings, and carrying the floor and roof beams of both of them. A party wall is sometimes owned jointly, when two persons own adjacent property—in this case the center line of the party wall marks one of the boundary lines of the lot—or the right to use the wall for floor and roof beams may be purchased at the time of the erection of an adjoining building.

The floor loads on party walls are obviously twice as great as the load on any outside wall; besides this, the necessity for thorough and complete fire protection must be greater in party walls than in outside walls, because the outside ones can easily be reached in case of fire, while party walls, being enclosed by other walls, are more difficult of access.

Building regulations differ materially in regard to the thickness of party walls. The general agreement is that no such walls should be less than 12 inches thick, and the best guide for determining the thickness of party walls is to make them 4 inches thicker in each story than the outside wall.

WOOD LINTELS AND WOOD BRICKS.

248. As a rule, no more woodwork should be placed in a wall than is absolutely necessary. Wooden lintels supporting walls are especially objectionable, because, besides being combustible, they are also liable to shrinkage. Framing lumber is very seldom thoroughly dry, and, when a brick wall is supported in part by a wooden lintel, a crack is almost sure to develop, as shown at *a* in Fig. 105. It is quite obvious that this crack is caused by the wooden lintel

b shrinking, and permitting that part of the brick wall resting on it to settle by an amount equal to the shrinkage of the wood, while the portion of the brick wall *c*, being carried on the brick pier, does not settle.

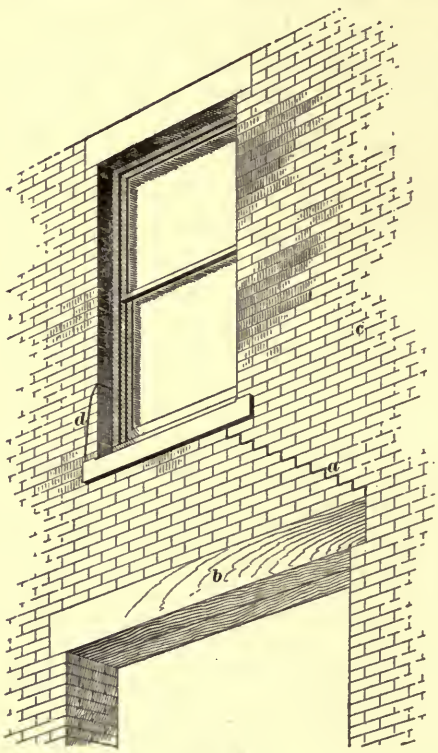


FIG. 105.

At *d*, Fig. 105, is shown a small crack such as is often seen just above the end of door or window sills. Such cracks usually occur near the bottom of high walls, and are caused by the compression of the mortar in the lower joints of the pier. If slip sills are used, these cracks may be avoided.

249. Sometimes, templets, formed of pieces of studding, are laid under the ends of floor joists to give a level bearing to the joists, and distribute the weight over the walls. Their use is not recommended, because they are very sure to shrink and leave the wall over them unsupported. If used at all, they should not be put in buildings over two stories high, and in walls less than 12 inches thick, and the very dryest, best seasoned timber procurable should be used.

Strips of wood are often built in the joints of brick walls, to form a nailing place for wood finish or furring strips. It is not well to use these in buildings over three stories high, because the weight of the wall and the shrinkage of the wood will cause the plaster to crack. If these nailing strips

are used, they should not be over ⅜ inch thick, or not wider than the mortar joints. Wooden bricks, that is, blocks of wood corresponding in size to the bricks in the wall, are sometimes built in for nailing places for door and window trim, furring, etc. The great objection to their use is that they generally shrink and become loose, thereby losing their holding power.

Porous terra-cotta blocks may be had, the size of a brick, and should be used as nailing blocks, in all first-class work. These blocks do not shrink, and will hold a nail as well if not better than wood.

DAMP-PROOF COURSES.

250. Moisture in wet ground is very likely to soak up into the walls from the foundation, thus causing the building to be very unhealthy and producing rot in the woodwork. To prevent the moisture from rising through the foundation walls, a horizontal damp-proof course should be placed in all walls just below the level of the first-floor joists. This damp-proof course should be at least 6 inches above the highest level of the soil touching any part of the outer walls, and should not be broken at any point in its length. It should run at least 2 feet into all cross-walls, and where the ground is very wet, it should be continuous through all walls.

In many cases, when buildings are finished with parapet walls, it is customary to put in a damp-proof course just above the flashing of the roof or gutter, in order that the dampness produced by driving rains may not soak down into the woodwork of the roof, and from there to the walls below.

251. Damp-proof courses may be made of hot asphalt and coal tar. They should be mixed in the proportion of 9 parts of asphalt to 1 of coal tar, and put on in a ⅜-inch layer, or the thickness of a mortar joint. The surface of brickwork that receives the asphalt should be quite dry and smooth, and the joints should be well flushed up with mortar.

Two courses of roofing slate, or very hard vitrified brick,

laid in sand-and-cement mortar with broken joints, form a cheap damp course; or a ½-inch layer of Portland cement mortar, mixed in the proportion of 1 part of cement to 2 of sand, is often used, but is not considered as desirable as the asphalt.

ORNAMENTAL BRICKWORK.

252. There are numerous ornamental effects produced by the varied use of bricks. First, there are the constructive features, such as arches, imposts, pilasters, belt and string courses, cornices, and panels. There is also a large field for design in surface ornament by means of brick of different shades or color laid to form a pattern. Both plain and molded brick may be used, although no very striking effects can be produced by the use of plain brick alone.

In most of the large cities there are manufactories of pressed brick, making a great variety of molded brick, by means of which almost any design in moldings, belt courses, etc. may be carried out. Molded-brick cornices, belt courses, and indeed any molded work built of brick are much cheaper than stone.

253. It is difficult in laying brick moldings to get them to run true and straight. Nearly all molded brick become somewhat uneven and distorted in contour from molding and burning, so that when they are laid in the wall, the ends that come against each other do not match evenly. Some manufacturers make molded brick that are almost, if not entirely, free from this defect; and if molded brick are to be used, the architect should endeavor to learn which kinds run the truest and make the most satisfactory work.

If the bricks are carefully averaged when laid, so that the ends will match as nearly as possible, and the joints are neatly ruled, the uneven effect may be largely overcome. The distortion shows less in header brick than in stretcher, because they have less surface to distort.

254. The projection of the brick in moldings, belt courses, etc. should be as small as possible to carry out the

design, in order that the brick may bond back into the wall. If the projection is too great, there is danger of the brick falling out.

When practicable, and the projection is not too great, it is better to use more stretchers than headers in a belt course, because it takes a less number of stretchers than headers to run a given number of feet, and the cost of the bricks is the same.

255. If possible, the top of all brick belt cornices should be laid in beveled brick, so as to give a wash to the top of the course. This is shown in Fig. 106, where *a* shows the beveled brick on top of the belt course, and *b* the coved

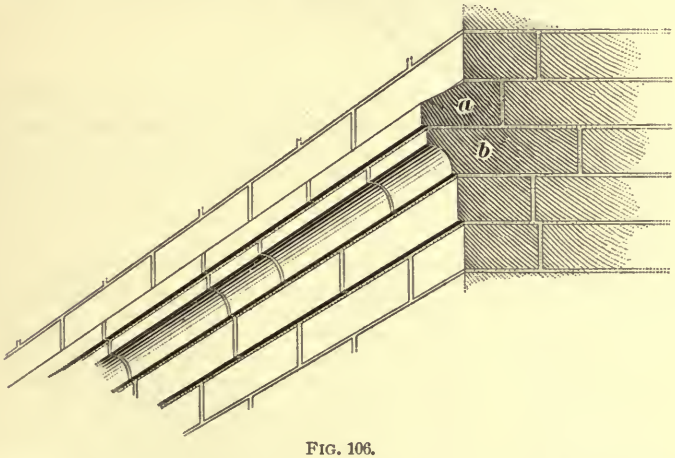


FIG. 106.

brick under the top course. The top course *a* should be laid as a stretcher course, provided it does not project more than 3 inches from the face of the wall; this reduces the number of end joints in the brickwork. The brick should be laid in cement, so that the mortar in the joints will not be washed out. If the top course *a* is built as a stretcher course, the course *b* should have at least every other brick a header.

256. When it is not possible to use beveled brick for the top course, some other means of protecting the upper surface should be used, as unless some precaution is taken

to protect the top of the projecting brick from the wet, the rain water will eventually soften the joint and penetrate into the wall. The end joints of the top courses are especially likely to be washed out. Fig. 107 shows the best

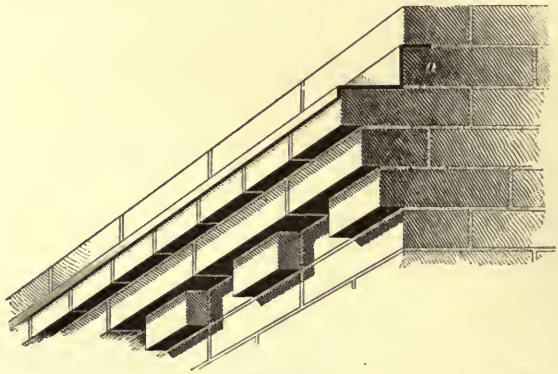


FIG. 107.

method of protecting the top courses, when beveled brick are not used; this is by means of lead sheets built into the second joint above the belt course, and turned down slightly over the face.

Another method consists of a beveled course of Portland cement, as shown at *a*, Fig. 108. This is not considered as

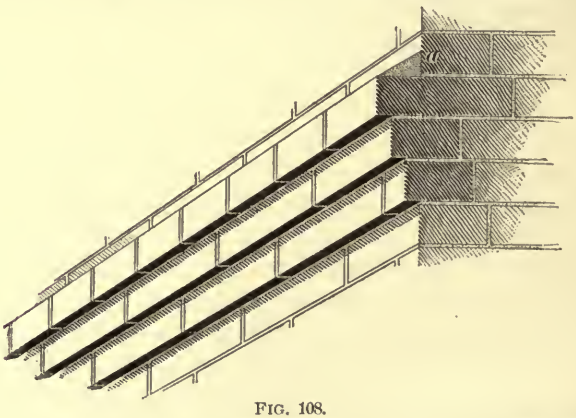


FIG. 108.

good as the lead, since the cement may become cracked and fall off.

BRICK CORNICES.

257. When brick buildings have a parapet wall and flat roof, and the item of cost has to be considered, a brick cornice is generally the most satisfactory, provided one of terra cotta cannot be afforded; and is very much better than a galvanized-iron or wooden cornice, for besides being more durable, it does not, like them, require painting at frequent intervals.

Where any considerable amount of projection is required, it is best to adopt some corbel treatment, building the corbel up by slightly projecting each course. This mode of laying brick cornices is shown in Figs. 109 and 110.

258. Fig. 109 shows an arched and dentiled cornice, very effective in high buildings, where a good shadow effect

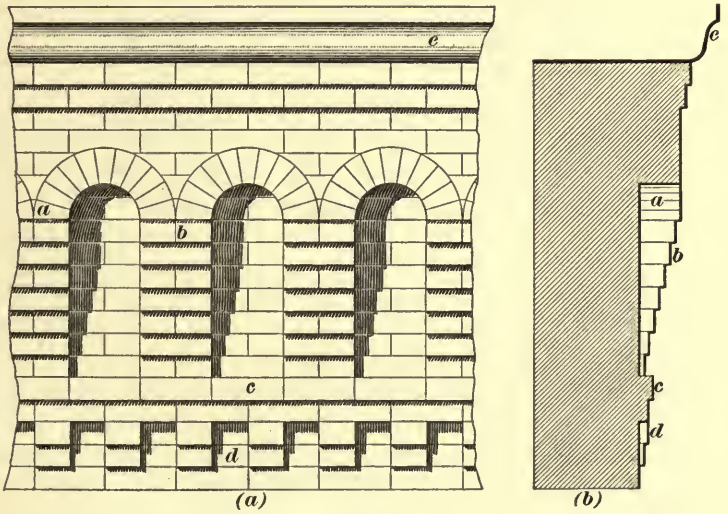


FIG. 109.

is desired without great projection. The cornice is shown in elevation at (*a*) and in section at (*b*). At *a* are shown the 4-inch brick arches between the corbels, composed of brick laid the 4-inch way; for very special work, these brick should be gauged, or rubbed, so that they will fit exactly in the arch. At *b* are shown the brick corbels, made 8 inches, or

one brick, wide, and seven courses of brick high, each course having a projection of slightly over $\frac{1}{2}$ inch; *c* shows the belt course, of two courses of brick, on which the corbels stop, the upper course projecting $\frac{1}{2}$ inch; and *d* is a dentil course of brick laid as headers, with a 4-inch space between each dentil, which is two courses in height, each course projecting $\frac{1}{2}$ inch; *e* shows a galvanized-iron crown mold that can be used to form a gutter if desired.

259. Fig. 110 shows a less elaborate and cheaper brick cornice. The elevation is shown at (*a*) and the section at (*b*); the crown course *a* is composed of two courses of brick, each projecting $\frac{1}{2}$ inch. The corbels *b* are each 4 inches or one-

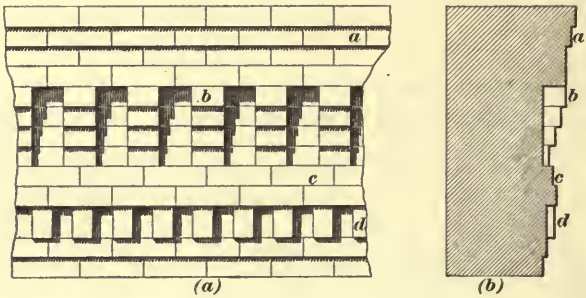


FIG. 110.

half brick wide, and are spaced 4 inches apart; three of the courses in each corbel project about $\frac{3}{4}$ of an inch each, making the whole projection about $2\frac{1}{4}$ inches. At *c* is shown the belt course on which the corbels stop, laid in two courses of brick, the lower course having a projection of $1\frac{1}{4}$ inches, and the upper course setting back $\frac{1}{2}$ inch from the face of the lower course. At *d* is shown the dentil course of brick set on edge, having a space between each dentil of $2\frac{1}{2}$ inches, or the thickness of a brick, and projecting 1 inch. The belt courses *c* should be protected on top from the weather by sheet lead, as shown in Fig. 107, or by Portland cement, as shown in Fig. 108.

260. A very effective brick cornice, especially for buildings of medium height, is shown in Fig. 111. This cornice

bonds well, gives a strong shadow, and is easily laid. At *a* is shown the two top courses of brickwork in the cornice; the bricks are laid up as stretchers, and the upper course projects $\frac{1}{2}$ inch over the lower, and the lower course $\frac{1}{2}$ inch over the dentil course. At *b* is shown the upper dentil course, pro-

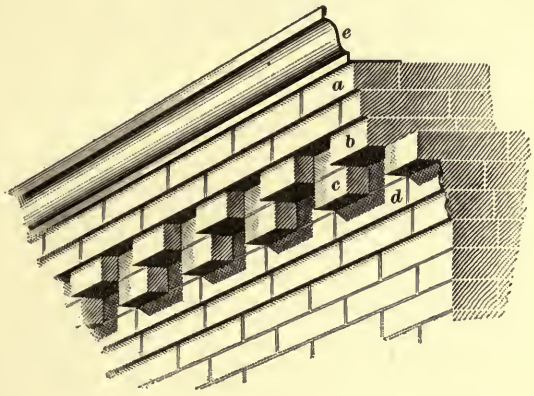


FIG. 111.

jecting $1\frac{1}{2}$ inches over the lower dentil course; *c* is the lower dentil course projecting 2 inches beyond the lower belt course; *d* is the lower belt course of two courses of brick, each one projecting $\frac{1}{2}$ an inch; and at *e* is shown the galvanized-iron ogee crown mold, which may also be used to form a gutter if desired.

BRICK ARCHES.

261. When there is sufficient height above a window, door, or any other opening in a brick wall, a brick arch, either circular or segmental, is used to span the opening, and forms a very durable and easily constructed support for the wall above. Whenever brick arches are built, great care should be taken in their construction, and they should be laid with full mortar joints. If the span is more than 10 feet, the arch should be laid in cement mortar; in fact, it is the best and safest to lay all brick arches in cement mortar.

262. When semicircular arches are constructed of common brick, the bricks are laid close together on the

inner edge, or *intrados*, with wedge-shaped joints on the outer edge, or *extrados;* that is to say, the mortar joints are wider at the upper surface of the brick ring than at the lower surface, so that there is more mortar at the top of the joint than at the bottom. The bed surfaces of the brick are therefore not on radial lines, as they are in a gauged brick arch, but the radial lines are assumed to pass through the center of each mortar joint.

Fig. 112 shows a semicircular arch consisting of four *rowlock* courses of brick. These arch brick are all laid as

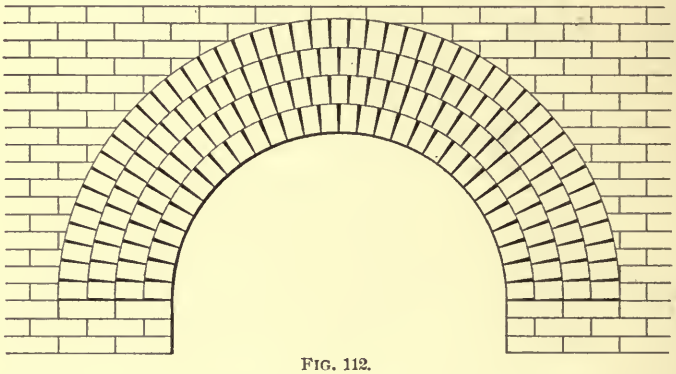


FIG. 112.

headers, and show an 8-inch reveal on the under side or *soffit* of the arch. Arches built in this way, of a series of rowlocks or concentric rings, have no connection between the rings other than that afforded by the adhesion of the mortar.

Rowlock arches are frequently bonded back into the rear wall with hoop iron let in at right angles to the joints.

263. In order to obtain a better bond, the arch shown in Fig. 113 is often used. This arch is bonded in several places, with *stretcher* brick set on end, serving the same purpose as *voussoirs* in stone construction. The *header* brick are shown at *a*, and the stretcher brick forming the voussoirs at *b*. An arch of this kind can be bonded back into the rear wall by the use of headers where the voussoir stretchers occur, and is known as a *block-in-course* arch.

264. In arches of large span built of common brick, especially in the brick lining of tunnels and vaults, the bond is

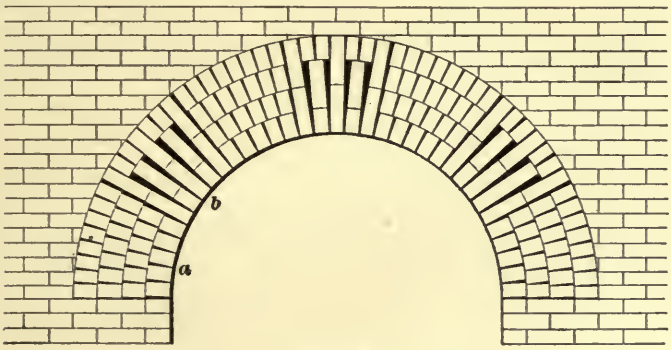


FIG. 113.

often effected by building in headers, which will unite the concentric rings where the joints of two of the rings come together.

An example of this is given in Fig. 114, which shows an arch of four rowlocks, two being header and two stretcher

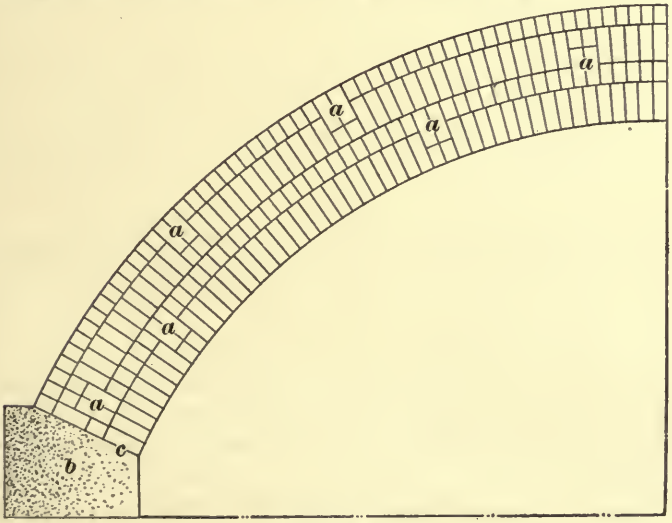


FIG. 114.

courses, the header and stretcher courses being bonded by headers, as shown at *a*.

265. Skewbacks.—When brick arches of large span are to be built, they should in all cases have a solid bearing for the arch to spring from; such a bearing is called a *skewback*, or springing stone, and is shown at *b* in Figs. 114 and 116. The stone should be cut so as to bond into the brickwork of the pier, and the surface *c*, that the arch springs from, should be cut to a true radial plane.

266. Fig. 115 shows a semicircular arch constructed of *gauged*, or *shaped*, brick. The gauging, or shaping, may be accomplished by laying out the arch ring on a floor, and cutting, rubbing, or grinding the brick to a certain gauge, or

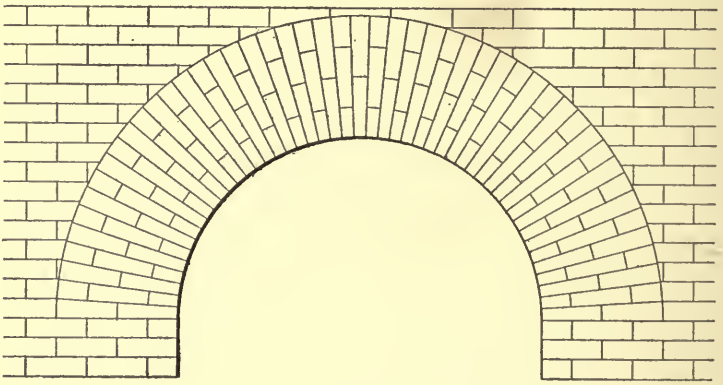


FIG. 115.

pattern, so that each brick will fit exactly in the place chosen for it, and all the mortar or radial joints will be of the same thickness throughout.

When the *reveal*, or space between the window frame and the outside of the wall, is only 4 inches, gauged-brick arches do not usually have any bond in the body of the wall, and the brick in the arch must be laid with great care and accuracy.

Gauged, or *shaped*, brick are supplied by most of the extensive pressed-brick manufacturers, who prepare the brick so that each one will fit accurately in its position in the arch. When these brick are ordered from the manufacturers, either

full-sized or large-scale drawings should be furnished, giving the span of the opening, the radius of the arch, and the depth of the reveal.

267. Figs. 116 and 117 give examples of brick *segmental arches.* Fig. 116 shows a three-rowlock arch constructed

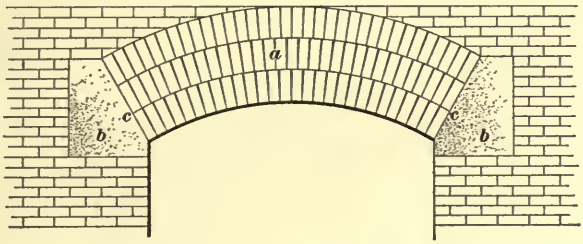


FIG. 116.

entirely of stretcher brick. This form of arch, unless bonded back into the rear wall with strap iron, is not a strong construction.

Fig. 117 shows a 12-inch segmental brick arch over a win-

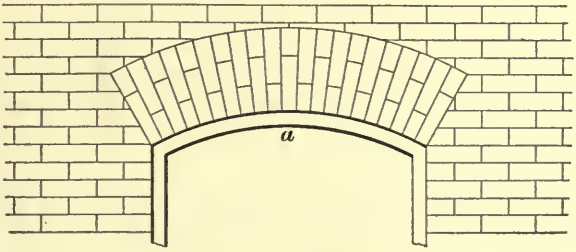


FIG. 117.

dow opening, with the arch constructed of gauged brick, and the window frame fitted into the head.

Fig. 118 shows a flat arch, bonded into the rear wall by the headers *a*, *a*. It is best to give the soffit of such arches a slight *camber*, or curve, as shown at *b*, because when they are made level they are almost sure to settle and sag a little, and crack the glass in the sash. In the plan of the window opening and sill shown at (*b*), Fig. 118, *a* shows the reveal of the brickwork; *b*, the 2-inch offset for the box frame of the

window; and *c*, the window sill. The section (*c*), Fig. 118, shows the under side, or soffit, of the arch at *a*, and the

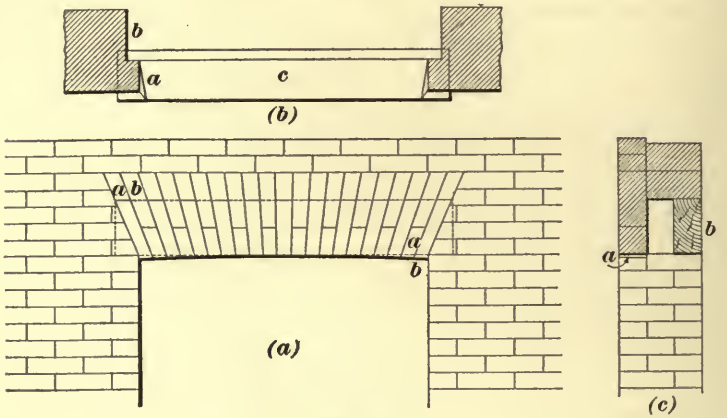


FIG. 118.

wood lintel at *b*. This wood lintel is placed behind the brick arch, and may also be used as a support for the floor joists. The lintel may have from 4 to 6 inches bearing at each window jamb.

RELIEVING ARCHES.

268. In place of *cambering* or curving the under side of a flat brick arch over an opening, the soffit is often made flat and is supported on an iron angle bar. This form of

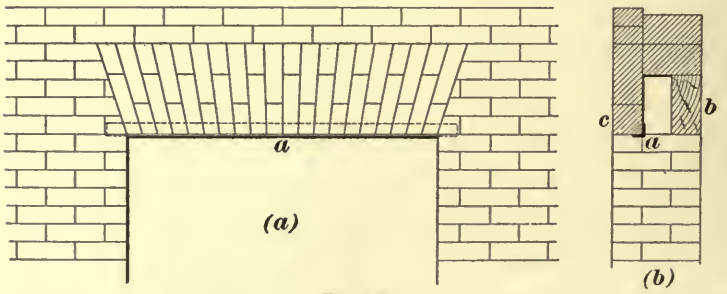


FIG. 119.

construction is shown in Fig. 119; at (*a*) is given a part elevation of a window opening with 12-inch flat arch, supported on $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{4}''$ iron angle as shown at *a*; (*b*), in the

same figure, shows a section through the arch, *a* being the iron angle, *c* the 4-inch brick arch, and *b* the wooden lintel behind the arch.

269. Sometimes, when the construction will admit, the wooden lintel may be cut on a segmental curve, as shown in

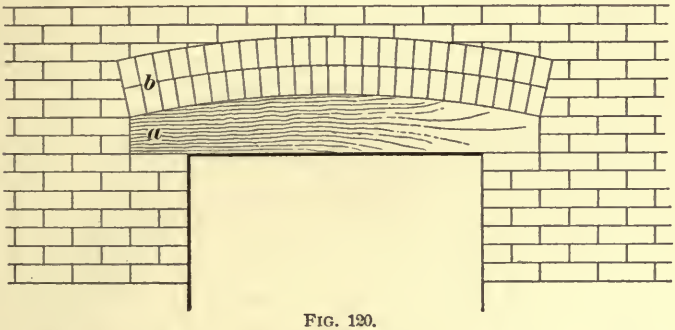


FIG. 120.

Fig. 120. In this sketch, *a* shows the 4-inch wooden lintel cut to the required curve, and *b* the two-rowlock brick arch resting on the curve of the lintel. This arch is called a *relieving arch*, because if there is any shrinking of the wooden lintel, there will be no settlement of the brickwork, the arch carrying the weight of the wall placed on it. Arches are usually built over stone lintels to keep them from cracking.

In some cases the arch is turned over an ordinary lintel, with the spring of the arch starting from the ends of the

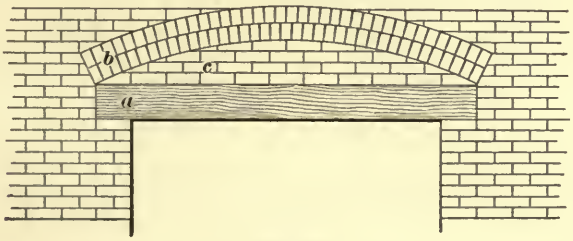


FIG. 121.

lintel, and a core of brickwork between the under side of the arch and the top of the lintel.

This is shown in Fig. 121; *a* is the lintel, which may be

either of wood or stone; *b* is the relieving arch, shown in this case as a two-rowlock arch; and *c* is the brick core between the lintel and the under side of the arch.

BRICK VAULTS.

270. Brick vaults are constructed in the same manner as common brick arches. The bricks are bonded lengthwise of the vault, with a header course every five or seven courses.

Vaults are sometimes built of a combination of brickwork and concrete, using light brick arches and backing up with concrete. They are also built entirely of concrete, the concrete being rammed on the centers in the same way that concrete footing courses are laid.

271. The ancient Romans adopted a method of constructing composite brick and concrete or masonry arches,

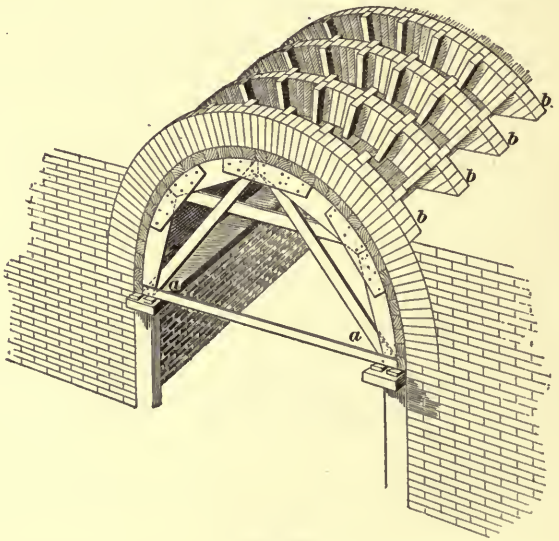


FIG. 122.

which is shown in Figs. 122 and 123. A light center of wood, shown at *a*, Fig. 122, was used, and on this, brick arches, as shown at *b*, were built. These brick arches were

called *armatures*, and as they are really the support of the vault, only very light wooden centers were required.

Fig. 123 shows the same form of arch with the spaces between the armatures filled with the concrete.

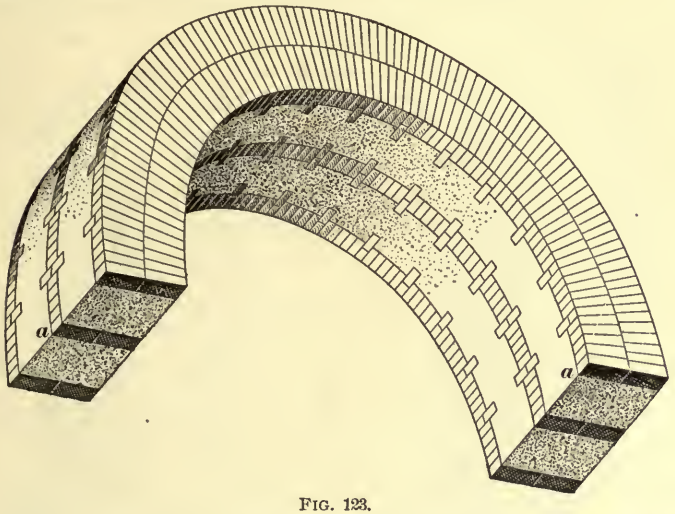


FIG. 123.

When vaults intersect each other, they are termed *groined vaults*, groined being the term applied to the curved intersection or arris of simple vaults crossing each other at any angle.

BRICK PIERS.

272. Brick piers are built in the same manner as brick walls. When they are less than 3 feet square, and support a beam, girder, arch, column, or lintel carrying a wall, the piers should, at intervals of not over 30 inches in height, have built into them bond stones not less than 4 inches thick, or cast-iron plates of sufficient strength and the full size of the piers. In height, isolated brick piers should not exceed 12 times their least square dimension.

The object of bonding a pier carrying a heavy weight is to distribute the load over the whole area, thereby causing the load to bear equally on each brick used in the construction.

The bond stones should be either granite, bluestone, or one of the durable limestones. The blue Vermont marble is also used, but the softer sandstones and freestones should be avoided.

Figs. 124 and 125 show the two types of bonded brick

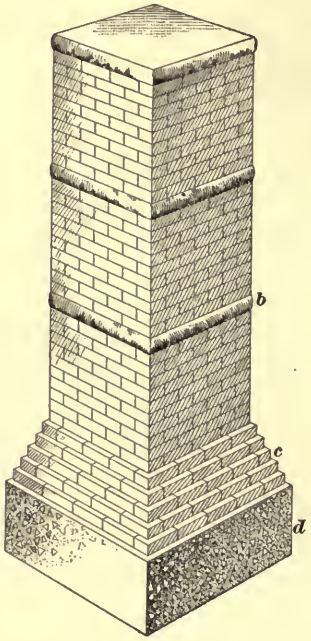


FIG. 124.

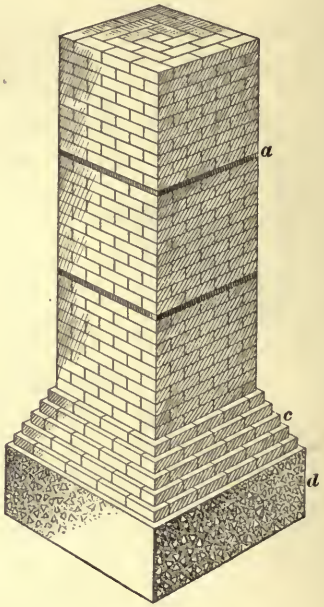


FIG. 125.

piers. Fig. 124 shows a pier bonded with 4-inch bond stones *b*, the stepped-off brick foundations at *c*, and the concrete base at *d*.

Fig. 125 shows a brick pier with 1-inch iron bonding plates at *a*, and the stepped-up brick foundation and concrete base at *c* and *d*.

BRICK NOGGING.

273. Stud partitions in brick buildings, and the space between the outside studs in wooden houses, are often filled in with brickwork, to obstruct as much as possible the

passage of fire, sound, and vermin. As there is no special weight placed on the brick, the cheapest kind of brick may be used for this purpose, such as the pale or *salmon* brick from the outer portion of a brick kiln. The brick should be laid in mortar as in a 4-inch brick wall.

When the wall is lathed with wooden laths, there should be a small space left between the brick nogging and the lath, so that the plaster will have a sufficient clinch behind the lathing.

If a stud partition rests on the capping of a partition below it on another story, the space between the floor and the ceiling below may be filled with brick nogging.

CLEANING AND PROTECTION OF BRICKWORK.

CLEANING DOWN.

274. The outside of a building, when faced with pressed brick, should be cleaned down soon after completion. This is done by washing and scrubbing the walls with muriatic acid and water, in the proportion of from 15 to 20 parts of water to 1 of acid. This is applied with scrubbing brushes or corn brooms, and the operation should be continued until all stains are removed.

While the cleaning is in progress, the open joints under all window sills, as also the joints in stone and terra-cotta work, should be pointed, so that the wall will be left in perfect condition when the cleaning has been completed.

275. The face of brick buildings, after a heavy driving storm of rain or damp snow, are often covered with a white *efflorescence*, which is very unsightly. This efflorescence is due either to soda in the bricks, which is drawn out by capillary attraction; to pyrites in the clay, which when burned form sulphuric acid, which unites with the magnesia in the lime mortar; or to salt in the sand. The efflorescence seems to appear after the bricks have been thoroughly saturated with moisture, either when laid or when exposed to a driving storm.

Boiled linseed oil prevents this discoloration if applied every three to five years. Any of the waterproof preparations mentioned under "Dampness in Walls" will keep the efflorescence off. Washing the wall in diluted muriatic or nitric acid will remove it; when the brickwork is dry, the oil or waterproof material may be applied.

PROTECTING OUTSIDE OF BRICKWORK.

276. After a driving rain or sleet storm, a wall even as thick as 12 inches may be soaked through by rain. It is therefore not desirable to plaster directly on the walls; if this is done, the wall should be either made waterproof, built hollow, or furred with $1'' \times 2''$ furring strips (though the last named does not prevent the moisture coming through the wall itself).

277. There are several ways of making brickwork impervious to moisture. It may be painted with lead-and-oil paint, coated with paraffin, or treated to some of the numerous patented processes.

All the paraffin preparations are applied hot, the wall being first heated by a portable heater. This makes the application expensive, owing to the time and labor involved.

In another process, known as *Sylvester's*, the wall is covered with two solutions, the first one made of castile soap and water, and the second of alum and water.

Boiled linseed oil is often used on brick walls, and two coats will usually keep out moisture two to three years. Linseed oil affects the color of the brick but little.

The objection to lead-and-oil paint is that it entirely changes the appearance of the brick and stonework. Indeed, architecturally speaking, pressed brick and stonework should not be painted unless it becomes absolutely necessary. If a new building is to be painted, the walls should be finished at least three months before painting, and then three coats should be given. This will usually last four or five years. Thereafter, one coat at a time will be found sufficient.

278. A liquid compound known as *Duresco* is manufactured in England and Germany, and has been used with good results in this country. Duresco has been successfully used to coat walls on the *inside* before they were plastered, and it is asserted that the passage of moisture through the plaster is thus successfully prevented. It is said that it not only makes the brick weatherproof, but improves their appearance. When dry, it has a hard, uniform, impervious surface, free from gloss, and will not flake off or change color. This preparation is imported in kegs containing 56 pounds, one of which will cover about 1,000 square feet with two coats.

A preparation manufactured in Boston, and known as *Cabot's Brick Preservative*, is extensively used, especially in the New England and Eastern states. It is claimed by the manufacturer that this compound will completely waterproof brickwork and sandstone, preventing efflorescence, the disintegration of brickwork by frost, and the growth of fungus. The natural texture of the material is not changed by the application of the preservative, which leaves no gloss. It is made colorless for use on any kind of brick, to make them waterproof; and with color added, to match the brickwork.

The material is put on with a painter's brush, as linseed oil, or lead-and-oil paint is applied. The brickwork should first be washed down with diluted muriatic or nitric acid. A gallon will cover about 200 square feet of ordinary rough brick, and one coat is generally enough, unless the brick are very soft and porous.

279. Asphalt, put on hot, and from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch thick, should be applied to the top of brick vaults to prevent the penetration of moisture. When the vault is covered with earth, it is well to lay the top course of brick in hot asphalt, in addition to coating it.

STRENGTH OF BRICKWORK.

280. As a usual thing, the brickwork in walls is of ample strength to carry the loads imposed. The principal loads come on the piers, arches, and under bearing plates. Of course, the strength varies, owing to different conditions

that may exist: the strength of the bricks taken separately, the materials and quality of the mortar used in laying the brickwork, the workmanship and bond, as well as the age of the brickwork. The following table gives the safe strength of brickwork based on the quality of the brick in various sections of the country:

TABLE 4.

STRENGTH OF BRICK MASONRY.

Materials.	Strength.	
	Pounds per Sq. In.	Tons per Sq. Ft.
Eastern Brick.		
Hard burned brick, laid in good lime mortar.....	100–140	7–10
Same, laid in 1 to 2 Rosendale cement mortar.....	150–165	$10\frac{3}{4}$–$11\frac{3}{4}$
Same, laid in 1 to 3 Rosendale cement and lime mortar....	195	14
Same, laid in 1 to 2 Portland cement mortar.....	210	15
Western Brick.		
Hard burned brick, laid in 1 to 2 Louisville mortar.....	145	$10\frac{1}{2}$
Same, laid in 1 to 2 Portland cement mortar	175	$12\frac{1}{2}$

The strength and efficiency of all brick-bearing piers depend largely upon the thoroughness with which they are bonded, and the architect or superintendent should carefully watch the building of them.

MEASUREMENT OF BRICKWORK.

281. In making a contract for brickwork, when the payments depend on the number of brick and other materials in the wall, it should be distinctly stated, in order to avoid disputes, how the work is to be measured and whether

or not deductions are to be made for the openings and stonework.

282. The usual method of measuring is by the thousand brick as laid in the wall. Most mason contractors, in estimating on the cost of brickwork, take the entire superficial area of the wall in square feet, measuring it on the outside of the wall, so that the angles are taken twice. This is done to allow for the extra labor in laying up the angles. The brick are then computed as laying $7\frac{1}{2}$ brick to the square foot to a 4 or $4\frac{1}{2}$ inch wall, 15 for an 8 or 9 inch wall, $22\frac{1}{2}$ for a 12-inch wall, 30 for a 16-inch wall, and so on, adding $7\frac{1}{2}$ brick per square foot for every additional thickness of 4-inch wall.

In figuring for the pressed brick, when the walls are faced with them, the whole superficial area of the wall is taken, and the 4 and $4\frac{1}{2}$ inch pressed brick facing is estimated at $7\frac{1}{2}$ brick to the superficial foot, to give the number of pressed brick in the wall. Deductions are made for *all* openings, and when the reveal of a window is more than 4 inches, the additional depth is figured and added to the whole number of pressed brick.

The figures above given apply to the Eastern and New England states. In the West and South the bricks are larger, and give from one-quarter to one-third less per square foot in the wall than in the East, and the price is regulated accordingly. In some parts of the West and South two measurements are used. The first, or *kiln count*, represents the actual number of brick purchased and used, while the second, or *wall measure*, designates the number of brick in the wall, estimating $22\frac{1}{2}$ brick to every superficial foot of 12-inch wall.

283. Among some builders the custom prevails to reduce all brickwork to cubic feet and estimate in that way. As for example, a wall 24 feet long, 12 feet high, and 20 inches thick would contain 24 ft. $\times$ 12 ft. $\times$ 1 ft. 8 in. = 480 cu. ft., at $22\frac{1}{2}$ brick per cubic foot = 10,800 brick.

284. Unless openings are very wide and numerous, it is not customary to deduct them in estimating for common brickwork. Hollow walls and ordinary chimneys with $8'' \times 8''$ or $8'' \times 12''$ flues are usually measured as though they were solid brickwork.

When the contractor who has the contract for the brickwork sets the stone caps, sills, quoins, belt courses, etc., no deduction is usually made for the pressed brick that would take the place of the stonework. If, however, the stonework is furnished and set by another contractor, an allowance is often made for the face brick displaced by the stone.

INSPECTION OF WORK.

285. The architect, when superintending the erection of brickwork, should see that sufficient mortar is used to fill all the joints, and that the bricks are *shoved* as described in Art. **190.** The quality of mortar should be frequently looked after, as sometimes, unless watched, brick masons will add loam to the sand to make the mortar *work well*, as it is termed. It is also important that the bonding of the walls should be well watched, in order to see that the number of bond courses, specified or required, are put in. Piers should be especially looked after, as their efficiency depends largely on the thoroughness of the bonding.

It should also be seen that the figured dimensions are properly checked and followed; all openings left in their proper places; courses kept level and walls plumb; that all bearing plates are well bedded; floor anchors securely built in; and that all recesses for soil, vent, steam and gas pipes are left in the proper places; also that all unfinished brick and stone work is properly protected from the weather.

MASONRY.

(CONTINUED.)

BUILDING STONE.

VARIETIES OF STONE.

1. It is necessary for the student of architecture to have a good knowledge of the different kinds of stone, in order to decide which is best to use under any usual condition. It can hardly be expected that he will be able to determine the exact composition of a stone, but his knowledge should be sufficient to aid him in selecting or specifying stone best adapted to the purposes for which it is to be used, when the time comes to put the information thus gained to practical use.

The following paragraphs describe some of the principal building stones of this country, classed according to composition and structure.

GRANITE, GNEISS, AND SYENITE.

2. **Granites** are generally massive in form, and compose the main part of most mountains. They are hard and granular in structure, the principal constituents being feldspar, mica, and quartz, in varying proportions. A granite containing much quartz is very refractory to work; as the proportion of quartz becomes less and that of feldspar increases, the stone works correspondingly easier.

The color of granite depends chiefly on that of the feldspar, but frequently it varies with the quantity of light or

dark mica contained in it. It is usually grayish in color, but may be obtained in all shades, even light pink and red being found in different localities. The light, fine-grained varieties are the most durable, but nearly all kinds have ample strength for ordinary purposes.

Granite may readily be quarried, as it breaks with regularity, and can usually be obtained of any required size. Great difficulty, however, is experienced in working granite, owing to its hardness and toughness, which make it very expensive to cut, and prevent its use in fine carving. Granite is probably the best stone for foundations, etc., and is extensively used in other positions requiring great strength, besides being put to such minor uses as flagging, thresholds, water-tables, etc.

All kinds of granite are damaged considerably by the action of fire, which causes them to crack badly. They disintegrate at temperatures ranging from 900° to 1,000° F.

Very good varieties of granites are found in many places in this country. Those of the Eastern states are probably the best known, but many other sections of the United States have stone in every way equal to them. Valuable quarries of granite are found at Vinalhaven and Hallowell, Me.; Quincy, Mass.; Concord and North Conway, N. H.; Westerly, R. I.; Barre, Vt.; St. Cloud, Minn.; Graniteville, Mo.; in Colorado, Georgia, and numerous other places.

3. Gneiss (pronounced *nice*) is constituted similarly to granite, but is distinguished from it by the somewhat parallel arrangement in layers. Owing to this peculiarity, the rock splits into slabs having approximately parallel surfaces, making it valuable for walls, street paving, etc. Gneiss is called by quarrymen *stratified*, or *bastard*, granite.

4. Syenite differs from granite and gneiss in containing no quartz. It is hard and durable, usually having a close texture, and a light-gray color. Like them, it is a very good building stone, and, except as above mentioned, has the same characteristics.

LIMESTONES.

5. Limestone is a term which includes all stones containing lime, although they may differ from one another in almost every other respect. Those used for building purposes have, besides lime, one or more of the following constituents: silica, clay, talc, hornblende, mica, carbonate of magnesia, and iron. Fossil remains, as shells, coral, etc., are often found in limestone, usually in a more or less pulverized condition.

The principal limestones used for building purposes are the common kinds, the fine-grained crystalline ones, usually called *marbles*, and the *magnesian* varieties. Limestones containing 10 per cent. or more of magnesia are called *magnesian*, and those having over 45 per cent. of it are termed *dolomites;* these are crystalline and granular in structure, and usually have a white or yellowish tinge.

In color, limestones are generally a light gray, blue, cream, or buff. The light-gray varieties frequently resemble the light, fine-grained granites. Examples of these are the Bedford, Ind., and the Bowling Green, Ky., limestones, which are both very durable and make excellent building stone.

The best limestones have a fine grain and weigh about 145 pounds per cubic foot.

6. Marble is a variety of crystallized limestone, and is much valued on account of its beautiful colors and its capability of taking a high polish. Nearly all kinds can be quite easily worked, and the fine-grained varieties are especially adapted for carving, and are particularly suitable for interior decoration. As it resists frost and moisture well, marble is also a valuable material for exterior construction.

Some of the finest varieties of white American marbles are found at Lee, Mass., and in the vicinity of Rutland, Vt. The dark-blue marble, from the Vermont quarries, is very durable and has a very close grain. A fine black marble is quarried at Glens Falls, N. Y. Colored marbles, including gray, light and dark pink, buff, chocolate, etc., are also found in Tennessee, Georgia, and elsewhere.

The strength of marble varies from 5,000 to 22,000 pounds per square inch.

7. The term *onyx* is applied to some kinds of marbles for the reason that their banded appearance somewhat resembles that of the true onyx. They have the same general composition as the common varieties of marble, but are formed in a purely chemical manner, instead of in ordinary sedimentary beds. Their variegated colors are due to the presence of metallic oxides and other impurities. Onyx can be worked and polished very readily, and is considered the handsomest of building stones, owing to its translucency and great variety of colors. It is used almost entirely for interior decoration, in wainscoting, mantels, etc. The stone presents the best appearance when cut across the grain, but this impairs the strength, and it is necessary to use backing of stronger marble. Most of the onyx used in this country comes from Mexico and California.

SANDSTONES.

8. Sandstones are so called because they are formed by the cementation of particles of sand—usually quartz grains—into rock. The character of the stone depends greatly on the nature of the cementing material. When this is composed wholly of silica, the stone has a light color and is hard to work. If the grains have been cemented by fusion, or under great pressure, the stone is nearly as hard as quartz; this variety is know as *quartzite*, and is very strong and durable. If the cementing materials are principally iron oxides, the stone is red or brownish in color, and is sufficiently soft to work readily. With carbonate of lime as a cement, the result is a light-colored or gray stone, soft and easy to work but which does not, as a rule, weather well. Sandstone containing clay is the poorest, as it easily absorbs water, which, on freezing, rapidly disintegrates the stone.

Sandstones include some of the finest and most durable stones for outside construction. The ease of working them,

and their wide distribution, cause them to be very extensively used. The stone is found in a great variety of colors —shades of gray, brown, buff, pink, red, drab, and blue being common—the color depending largely on the quantity of iron oxides contained in the stone. The presence of these is not injurious, but no sandstone containing iron pyrites should be used for outside work, as it is almost sure to become stained by rust.

Sandstones vary in texture from those in which the grains are almost imperceptible, to those having grains like coarse sand. The fine-grained stones are generally the most durable, and can be given sharp edges. Quarried sandstones usually hold considerable water, which renders them soft and easy to work; but nearly all become harder as the water evaporates, and until the water is dried out, the stone should not be subjected to heavy loads.

9. **Blue shale,** or **bluestone,** is a variety of argillaceous, or clayey, sandstone, having a bluish color, and is very hard and dense, making an excellent material for foundations, flagging, etc. It is found in large quantities along the Hudson River, in the vicinity of Kingston, N. Y.

QUALITIES OF GOOD STONE.

10. No branch of mason work, from an architectural standpoint, is of greater importance than the selection of stone for structural purposes; and the qualities of stone, such as its strength and durability when exposed to great variations of temperature and action of the weather, its permanence of color, etc., are points to be studied with great care.

11. **Strength.**—Whenever a stone is to be used for foundations, piers, lintels, bearing blocks, etc., its strength is a matter of importance. If the stone appears to be a first-class one, its strength may be assumed as equal to the average strength of stones of that kind, as determined by experiment.

The cap and bond stones for piers carrying iron columns,

and the bearing blocks under the ends of the girders, should be either granite, bluestone, or hard, blue Vermont marble. For use in such situations, the safe bearing strength should not be assumed greater than one-tenth of the crushing strength. The stones in piers, etc., in warehouses and office buildings, are often subjected to loads of from 60,000 to 70,000 pounds per square foot.

12. Table 1 gives the load per square inch at which the different kinds of stone fail.

TABLE 1.

CRUSHING STRENGTH OF STONE.

KINDS OF STONE.	STRENGTH, LB. PER SQ. IN.
Granites—	
Staten Island, blue	22,250
Maine	15,000
Quincy, Mass.	17,750
Richmond, Va.	21,250
Cape Ann, Mass.	12,420 19,500
Westerly, R. I.	14,940
Fall River, Mass.	15,940
Duluth, Minn.	17,750
Maryland Granite Co.	19,430
Limestones—	
Glens Falls, N. Y.	11,475
Lake Champlain, N. Y.	25,000
Kingston, N. Y.	20,700
Joliet, Ill.	16,900
Lime Island, Mich.	23,000 18,000
Bardstown, Ky.	16,250
Cooper Co., Mo.	6,650
North River bluestone	19,820
Marbles—	
East Chester, N. Y.	13,500
Italian, common	13,060
Dorset, Vt.	7,610
Proctors, Vt., blue	14,410
Lee, Mass., white	13,440
Mill Creek, Ill., drab	9,700
North Bay, Wis., drab	20,000

TABLE 1—*Continued.*

KINDS OF STONE.	STRENGTH, LB. PER SQ. IN.
Sandstones—	
Little Falls, N. Y., brown	9,850
Belleville, N. J., gray and red	11,700
Middletown, Conn., brown	6,950
Haverstraw, N. Y., red	4,350
Medina, N. Y., pink	17,700
Berea, O., drab	7,250 to 10,250
Vermilion, O., drab	8,850
Marquette, Mich., gray	7,450
Seneca, O., red brown	9,700
Cleveland, O., olive green	6,800
Albion, N. Y., brown	13,500
Kasota, Minn., pink	10,700
Frontenac, Minn., light buff	6,250
Dorchester, N. B., freestone	9,150
Massillon, O., yellow drab	8,750
Warrensburg, Mo., blue drab	5,000

13. Weight of Stone.—The following are average weights of stone of the class mentioned, per cubic foot:

Marble, in blocks..... 170 pounds.
Limestone, in blocks..... 158 pounds.
Granite, in blocks..... 167 pounds.
Sandstone, in blocks..... 139 pounds.
Slate, in blocks..... 174 pounds.

The New York, Boston, and Chicago building laws give the weight of building stone of all kinds, when laid in the wall, at 165 pounds per cubic foot, which is near enough for most computations.

14. Color.—In rural districts and places where little or no soft coal is consumed, light-colored stones may be used, with little liability of their becoming dirty or disfigured, while in very smoky cities they will become very dark in a few years. In such cases, the red or brown silicious, or flinty, sandstones are the most durable; and next in value are the granites. The stone which retains its native color

best is the most desirable to use; but, when it does change, the one most to be preferred is that in which the alteration is as little as possible, and uniform throughout.

15. Durability.—The durability of stonework is of prime importance. If the stone will last only a comparatively short time, it is practically throwing away money to use such a poor kind. It is evident, therefore, that buildings of importance should be constructed of the most durable materials to be had.

The following table, from the census of 1880, gives the length of time that the several varieties of stone named have lasted in New York City without material deterioration:

Brownstone, coarse	5 to 15 years.
Brownstone, fine laminated	20 to 50 years.
Brownstone, compact	100 to 200 years.
Bluestone (blue shale)	100 to 200 years.
Sandstone, Nova Scotia	50 to 100 years.
Limestone, Ohio, best silicious	100 to 200 years.
Limestone, coarse fossiliferous	20 to 40 years.
Limestone, oolitic	30 to 40 years.
Marble, coarse dolomite	40 to 50 years.
Marble, fine dolomite	50 to 100 years.
Granite	75 to 200 years.
Gneiss	50 to 200 years.

16. Probably ordinary variations of temperature test building stones most severely. Stones consist of particles cohering more or less closely, and an increase in temperature causes each particle to expand, tending to force apart those surrounding it; while with a lowering of temperature a corresponding contraction occurs. As the temperature is ever varying, there is a continual motion of the particles, which, although very small, will, in course of time, produce cracks and result in the slow and gradual destruction of the stone. Such changes are among the most potent causes of the disintegration of stone.

The effect of frost on stones saturated with moisture is always disastrous. The expansive force exerted by water in

solidifying is nearly 140 tons per square foot; hence, a stone of open texture, which is exposed to heavy rains, and then to the action of frost, must suffer deterioration in course of time. Sandstones are the most porous, and granites the least. For this reason, granite is best adapted for use in wet places, as in foundations, etc.

Stone should always be laid on its natural bed wherever possible. If placed so that the layers are vertical, water penetrates between them much more easily, and, on freezing, will very quickly split the stone. Stones, such as sill and belt courses, so placed that rains wash over them, will deteriorate much more rapidly than the rest of the masonry, and on this account should always be the most durable kinds.

17. Atmospheric gases, when brought by rains into contact with the exposed surfaces of some kinds of stone, often affect their durability. The changes are the results of oxidation and solution. When iron exists in stone in the form of pyrites, it becomes combined with the oxygen in the air, producing discoloration, known as *rust*. When very minute, these particles of iron pyrites are not injurious, and the only effect of the rust is to give the stone a yellowish tinge. But if the pieces are of considerable size, the oxidation will discolor the stone unevenly. Some authorities say that the presence of pyrites in small quantities is beneficial to the stone, increasing the tenacity by its cementing qualities.

18. Pure water has practically no effect on building stone. Rain, however, contains traces of nitric, sulphuric, and other acids, absorbed from the smoke, etc. in the air. These, when brought in contact with stones, tend to dissolve such portions as are soluble. Lime and magnesia in the form of carbonates (as in all marbles and limestones) are, in particular, easily acted on. Sandstones containing iron or lime suffer from the same causes, while granites are the least affected.

19. Heavy pounding or hammering tends to destroy the cohesion of the grains, thus rendering the stone more

readily acted on by the atmosphere. Only granites and the hardest sandstones should be peen or bush hammered. The most durable surface for granite is *rock faced*, as the crystalline facets, being but little disturbed in the dressing, shed moisture readily. For other stones, however, a smooth surface is usually the best in a changeable climate. Quarrying by explosives often causes cracks in the stone, so small as to be unseen until the application of the load increases them enough to make them visible. The fracture of stones in buildings is often due more to imperfect setting than to any lack of strength in the stone.

For some purposes, as for steps, door sills, paving, etc., the *hardness* of a stone is of importance, in which case granites and other hard stones are the most suitable.

20. In selecting building stone, it is often a point of much importance that it should have good fire-resisting properties. The fine-grained compact sandstones endure fire the best; while the exposed surfaces of limestones and marbles become converted into lime by intense heat. Granites are more affected than sandstones, but less than limestones.

21. Seasoning Stone.—In order to evaporate the quarry water, which most limestones and sandstones contain when freshly quarried, they should be exposed to the air for a considerable time before being used, as this seasoning makes the stone harder, and more durable under the action of frost. It is supposed that the quarry water contains in solution considerable cementing material, which is deposited when the water evaporates, firmly binding together the particles. It can readily be seen that such kinds of stone should have all necessary cutting, or carving, on them done as soon as possible after quarrying.

INSPECTION AND TESTS.

22. A close inspection should be made of all stone before it is used, to see that the specified quality is being delivered. A visit to the quarry is advisable when large

quantities of stone are to be used, in order to make any necessary tests of the stone. The tests usually made to assist the architect in determining the qualities of stone as to durability, etc., are for *compactness* and *hardness*, *absorption* and *solubility*.

23. Compactness.—The densest and strongest stones are also, in general, the most durable. An idea of the compactness may be obtained by examining, through a good magnifying glass, the surfaces of freshly fractured stone, which should show a clear and bright surface, with the particles well cemented. A dull, earthy-looking fracture indicates liability to quick deterioration. A clear metallic sound, when struck with a hammer, is a good test of stone.

24. Absorption.—The tendency of a stone to absorb water should be considered as to the effect on the appearance of the building. While a dense, non-absorbent stone is restored to its original color by a heavy rain, one of open texture quickly absorbs the water, which carries into the pores of the stone dust and soot, that soon make it very dirty.

Generally the most durable stones are those which absorb the least water. In order to test the absorptive qualities of a stone, a good average specimen of it should be thoroughly dried, carefully weighed, and immersed in water for 24 hours. When taken out, the surface moisture should be dried off, and the piece weighed; from the gain in weight, a good idea of the value of the stone may be obtained. One that increases 10 per cent. in weight in 24 hours should be rejected, unless it can be shown that such stone has endured successfully, for an extended period, the tests of time and weather. Even one absorbing 5 per cent. of water, and containing a considerable proportion of clay, is unsafe to use.

25. Solubility.—To determine whether a stone contains much easily soluble earthy or mineral matter, crush finely a sample of the stone and place the pieces in a glass of water, letting the particles remain undisturbed for about half an hour; then give the contents of the glass a rotary motion by stirring. If the stone contains much earthy matter, the

water will assume a turbid appearance, while if it has but little, the water will remain clear.

As before stated, the air in manufacturing cities is very likely to contain traces of various acids, which attack the stone when brought into contact with it by rain. To determine the probable effect of acids on stone, soak a piece in a dish of water containing a drop or two of muriatic or sulphuric acid. If there is a very noticeable action, it will be wise to further test the stone.

STONE CUTTING AND FINISHING.

26. Before treating of stone masonry, it is proper to consider the preliminary work of dressing the component stones in the wall. Therefore, if the architect desires to specify correctly the manner in which he wishes the stone to be finished, he should be familiar with the names and uses of the various tools used in stone cutting; and also with the technical names applied to the different sorts of finish of the stonework.

STONE-CUTTING TOOLS.

27. The **double-face** hammer, shown at (*a*), Fig. 1, weighs from 20 to 30 pounds, and is used for breaking and roughly shaping the stones as they come from the quarry.

The **face** hammer, shown at (*b*), is a lighter tool than the double-face hammer, but is used for the same purposes when less weight is required. It has one blunt and one cutting end, the latter being used for roughly dressing the stones preparatory to using the finer tools.

The **pick**, shown at (*c*), is used for coarsely dressing the softer stones. Its length is from 15 to 24 inches, and the width at the eye is about 2 inches.

The **ax**, or **peen** hammer, is shown at (*d*). This hammer is about 10 inches long and has two cutting edges, about 4 inches in length; its principal uses are in making *drafts*, or margin lines, around the edges of stones, and also for dressing the faces, being used after the point, and before the patent hammer.

The **tooth ax**, shown at (*e*), has its cutting edges *a* notched

to form teeth, the number varying according to the fineness of the work. Its principal use is to reduce sandstones to a level, ready for the crandail, or tool. It is not used on hard

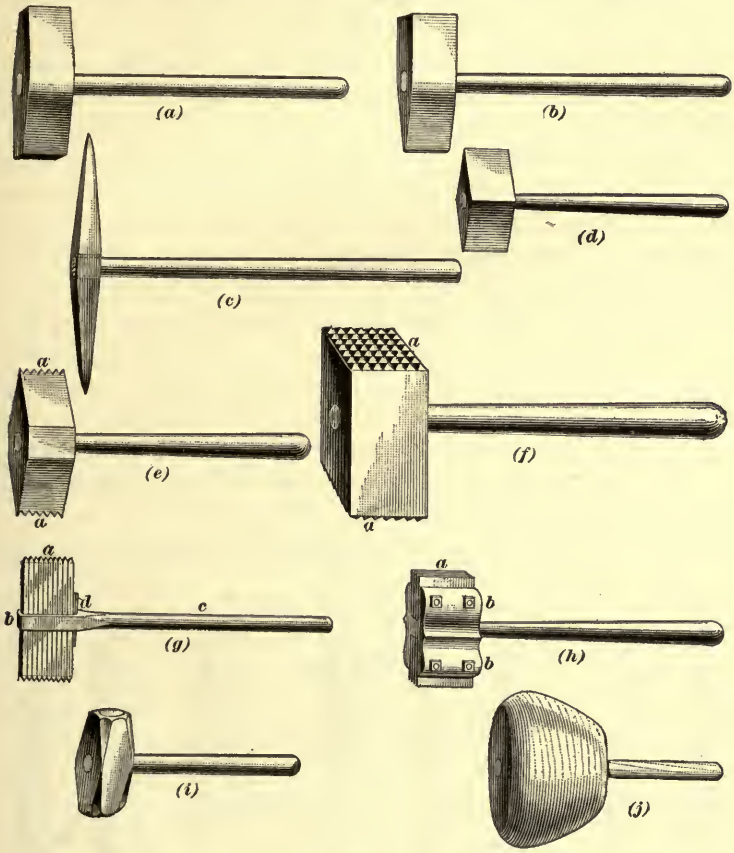


FIG. 1.

stones like granite and marble, as the points would quickly become dull and need constant sharpening.

The **bush** hammer, shown at (*f*), is from 4 inches to 8 inches long, with ends from 2 to 4 inches square, cut into a number of pyramidal points, as shown at *a*. This hammer is used for finishing limestones and sandstones after the surfaces have been made nearly even.

The **crandall,** shown at (*g*), is made from a malleable-iron bar *c* about 2 feet long, slightly flattened at one end *b*, which has a slot, $\frac{3}{8}$ inch wide and 3 inches long, cut in it. Ten double-headed points *a*, made of $\frac{1}{4}$-inch square steel, about 9 inches long, are inserted and are held in place by a key, shown at *d*. The crandall is used to complete the finish of sandstone after the surface has been partially worked by the tooth ax, or chisel.

The **patent** hammer, shown at (*h*), is made of from four to ten thin blades of steel *a*, which are ground to an edge and held together by bolts, as shown at *b*, so as to form a single piece. It is used for finishing granite or hard limestone, and the number of blades required to give the proper fineness to the cutting is usually specified as 4, 6, 8, or 10 cut.

The **hand** hammer, shown at (*i*), is used for drilling holes, and in pointing and chiseling the harder rocks. It is about 5 inches in length, and weighs from 2 to 5 pounds.

The **mallet,** shown at (*j*), is used when the softer stones are to be cut. It is made of wood, the head being about 7 or 8 inches in diameter, and 5 or 6 inches high.

28. Chisels. — Fig. 2 represents the different chisels

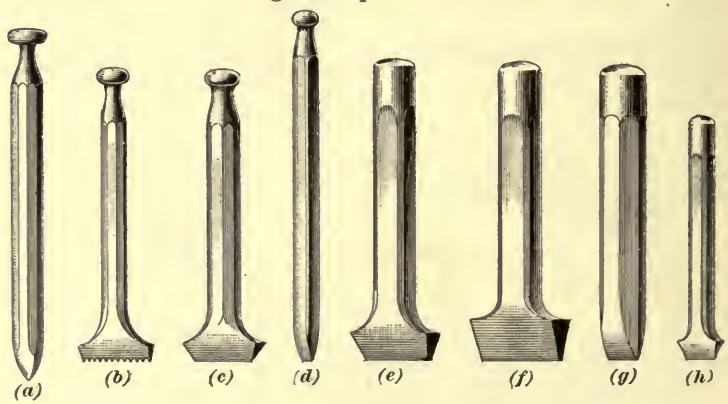


FIG. 2.

used in dressing stone. At (*a*) is shown the *point*, which is made of round or octagonal steel, 8 to 12 inches long, with one end pointed. It is used for chipping off the rough

faces of the stone and reducing them to approximately plane surfaces, ready for the peen hammer. It is also used to give a rough finish to stone in *broach* and *picked* work. At (*b*) is shown the *tooth chisel*, used only on soft stones, and serving much the same purpose as the tooth ax. At (*c*) is shown a *drove chisel*, 2 to 3 inches long at the end, used for cutting or *driving* the rough surfaces of the stone. At (*d*), (*e*), (*g*), and (*h*) are shown other forms of chisels used for dressing soft stone. At (*f*) is shown a *pitching chisel*, used for making pitched-face work, as shown in Fig. 3.

29. Machine Tools.—Besides the hand tools described in the previous articles, there are a number of machine tools used to prepare the stone for the finer treatment to be given by hand work. These include saws, cutters, planers, grinders, and polishers.

The saws are either drag, circular, or band saws, each consisting of a thin sheet of steel, and having blunt edges. The former has a forward and backward movement, the cutting being done by aid of sand and water fed into the cut. The operation of the others is similar, except as to the manner of driving.

The cutters are used on the rough stone to somewhat reduce the inequalities. Cutters and planers are made on two principles, one kind being used for homogeneous and tough stones, free from grit, etc., which are dressed by machines resembling those used for iron and steel; the other kind is for hard, brittle stones, whose structure necessitates a treatment resembling that employed in hand dressing. From the cutter and planer the stone goes to the grinder and polisher, which are practically alike, differing only in the fineness of the surface which they are capable of producing. A polisher consists principally of a large plate of iron, revolving horizontally, upon which the stone to be polished is laid, but is secured to prevent its moving with the plate. Sand and water is supplied between the disk and the stone, whose surface is thus abraded till the proper degree of smoothness is attained.

FINISH OF STONEWORK.

30. As the method of forming plane and curved surfaces on stone will be the subject of a separate section, *Stereotomy*, it will not be taken up at this place; only the different surface finishes will be here described.

FIG. 3.

31. Fig. 3 shows **rock-faced,** or **pitch-faced,** work, and the method of using the pitching chisel. The face of the stone is left rough, just as it it comes from the quarry, and the joints, or edges, are pitched off to a line, as shown at *a*. As but little work is required for this finish, rock-face dressing is cheaper than any other kind, especially when granite or hard limestone is used.

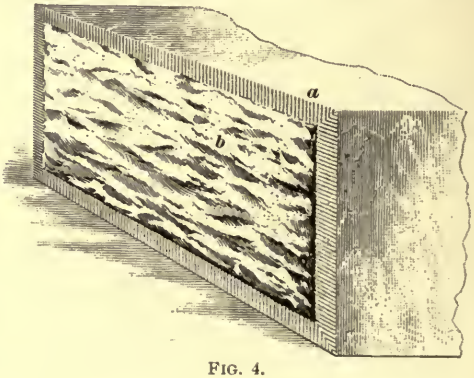


FIG. 4.

32. Margins.— The next step in dressing stone consists in cutting *margin*, or *draft lines*, as shown at *a*, Fig. 4, the rock-face surface of the stone being indicated at *b*. The margin is cut with a chisel on the soft stones, and with an ax on granite.

33. Broached Work.—Fig. 5 shows what is known as *broached work*, by which the stone is dressed so as to leave

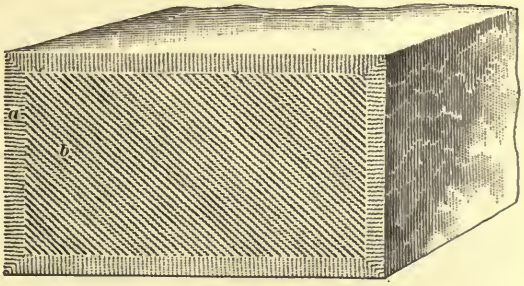


FIG. 5.

continuous grooves over the surface. At *a* is shown the margin, or draft line, and at *b*, the broached center.

34. Pointed Work.—When it is not necessary to dress the faces to less than $\frac{1}{4}$-inch or $\frac{1}{2}$-inch projections, and when a smooth finish is not required—as in the case of basement walls and piers—the rough faces of the stone are taken off with a point, and the surface is *rough* or *fine pointed*, according as the point is used over every inch or every half inch of the stone. Figs. 6 and 7, respectively, show rough and

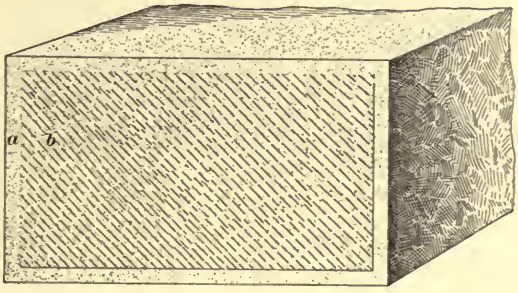


FIG. 6.

fine pointed work, *a* being the draft line, and *b* the pointed surface.

35. Tooth-Chiseled Work.—This is one of the cheapest methods of working stone, and is done with the tooth

chisel, shown at (*b*), Fig. 2, which gives a surface resembling pointed work, but not as regular.

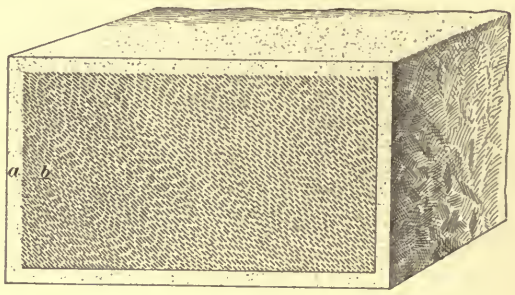


FIG. 7.

36. Tooled Work.—For this finish, a chisel from 3 to $4\frac{1}{2}$ inches wide—see (*e*), Fig. 2—is used, and the lines are continued across the width of the stone to the draft line (when one is used), as shown in Fig. 8. When well done, it makes a very good finish for sandstones and limestones.

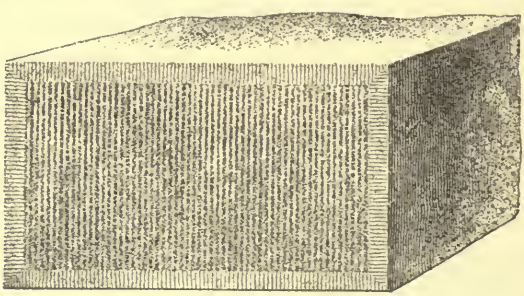


FIG. 8.

37. Drove Work.—This is similar to tooled work, but a flat chisel, about $2\frac{1}{2}$ inches wide—shown at (*h*), Fig. 2—is used. The finish represented in Fig. 9 does not take quite so much time as tooled work, and is, therefore, considerably cheaper, but does not look so well, as the dressing extends over only a portion of the surface, and the lines are broken.

38. Crandalled Work.—Fig. 10 shows the two kinds of crandalling, *a* representing the appearance when the

lines all run the same way, and *b* showing the lines crossing. When the work is well done, the stone assumes a fine, pebbly appearance. This finish is especially effective for

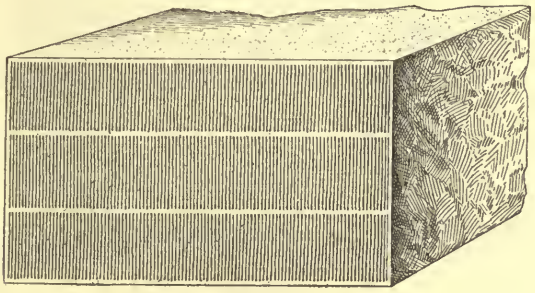


FIG. 9.

the red Potsdam and Longmeadow sandstones. In the Eastern states, it is used for sandstones probably more than any other finish.

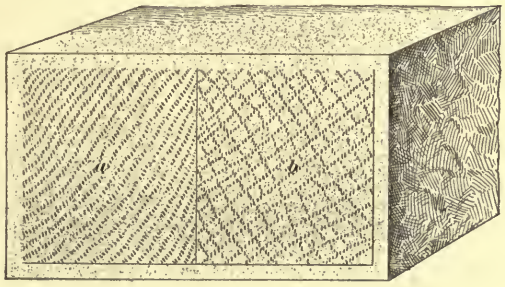


FIG. 10.

39. Rubbed Work.—Sandstones, and most of the limestones, are often finished by *rubbing* their surfaces until they are perfectly smooth. This may be done either by hand, using a piece of soft stone, with water and sand, or by a machine which performs the same operation. If the rubbing is done soon after the stones are sawed into slabs, and are yet soft, it is very cheaply and easily performed, as the sawing makes the face of the stone comparatively smooth. By continuing the rubbing long enough, granite, limestone, and marble can be given a beautiful polish.

40. Bush-Hammered Work.—Fig. 11 shows the finish of a stone after having been bush hammered, which leaves

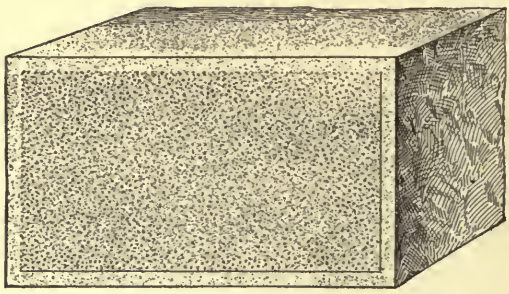


FIG. 11.

its surface full of points. This makes a very attractive finish for hard limestones and sandstones, but should not be used on the softer kinds.

41. Patent-Hammered Work.—Fig. 12 shows a stone finished by a patent hammer, which is generally used on granite and hard limestone. The stone is first dressed to a fairly smooth surface with the point—shown at (*a*), Fig. 2—and

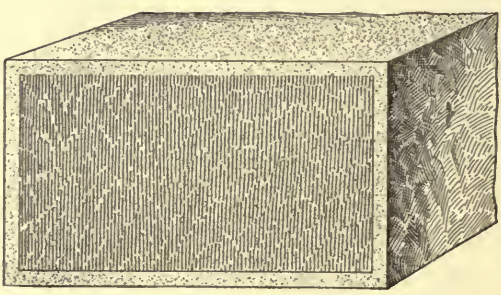


FIG. 12.

is then finished with the patent hammer. The degree of fineness in the finish is determined by the number of blades in the hammer. For United States government work, 10 cuts per inch are generally specified, while ordinary work usually has 8 cuts. The ax—see (*d*), Fig. 1—may also be used, but much more time is required to obtain the same finish.

42. Vermiculated Work.—In Fig. 13 is shown a stone of somewhat elaborate finish, known as *vermiculated*, from the worm-eaten appearance. Stones so cut are principally

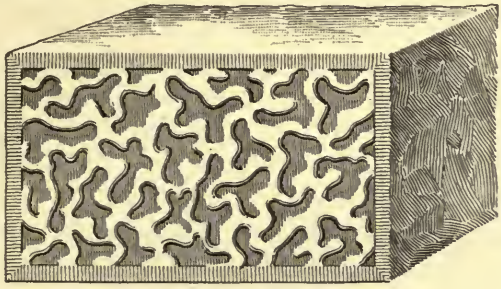


FIG. 13.

used as quoins and in base courses. Owing to the cost, this dressing is not often used in this country, except for the most expensive work.

43. Rusticated Work.—This term is now generally used to designate sunk or beveled joints, but originally was applied to work honeycombed over the face, to give a rough effect, as in Fig. 25. Figs. 14 and 15 represent examples of rusticated

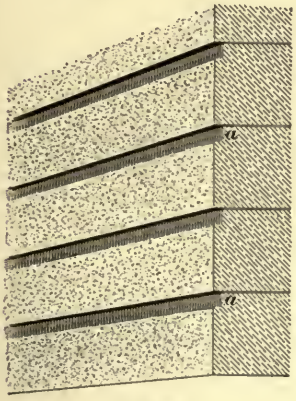


FIG. 14.

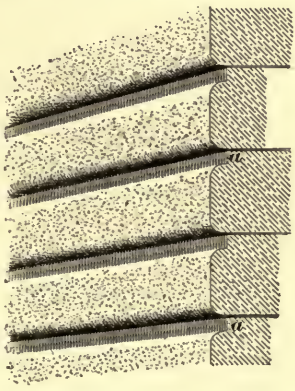


FIG. 15.

work, the former showing square recessed joints at *a*, and the latter, rounded exterior edges. This finish is used largely for basement work, and to emphasize piers and other projections.

STONE MASONRY.

GENERAL CONSIDERATIONS.

44. The stonework which enters into the construction of buildings may be divided into three classes: *rubble*, *ashlar*, and *trimmings*. Before describing these, however, a few general observations, applying to all classes of stone masonry, are necessary.

45. Whatever may be the quality of mortar used, the wall should contain as much stone and as little mortar as possible, as the former is the stronger material. In rough walling, if the stones are pressed together until the more prominent angles on their faces come almost into contact, the interstices being filled with mortar, there results better work than if a thick, yielding mass of mortar is allowed to remain in the joints. Absolute contact is not advisable in stonework, any more than in brickwork, as the shrinking of the mortar in drying may leave the stones bearing only on the projecting angles.

The joints in stonework vary in thickness from $\frac{3}{16}$ inch to $\frac{1}{2}$ inch; a $\frac{1}{4}$-inch joint is probably the best for ordinary work, while a $\frac{1}{2}$-inch joint should be used for rock-faced work only.

46. Stone being of a brittle nature, the longer pieces in a wall must be properly supported and well bedded, in order to prevent their breaking, and it is best to avoid extremely long lengths. There is a certain medium which should be observed; and while in stone, as well as in brick walls, a compact mass, as little broken as possible, is most desirable, yet the mason will often find it better to break a very long stone into two or more shorter ones, even though by so doing he makes additional joints.

47. All bed joints in stonework should be full and square to the face, and in no case made as shown at *a*, Fig. 16. If the joints are hollow, the least settlement will throw the whole pressure upon the edges of the stone, and cause spalls

to break off, which action not only spoils the appearance, but also endangers the stability of the walls. Stone cutters very often work the joints hollow, and leave the back of them slack, as shown at *a*, Fig. 17, as it requires less work than

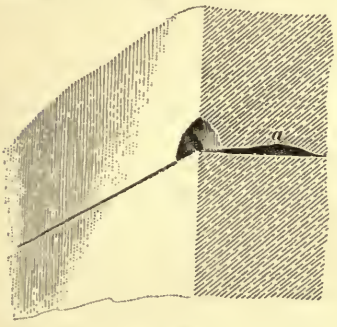


FIG. 16.

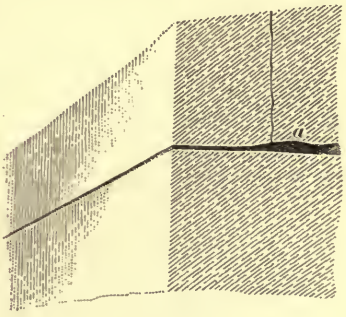


FIG. 17.

to dress them properly. If the back of the stone is thus left slack and underpinned, it is liable to break in the middle. It is also necessary that the abutting surfaces should not be convex, so as to rock on each other and cause instability.

Rusticated joints, as shown in Figs. 14 and 15, are often used in the basement and first story of many tall buildings, to lessen the liability of spalling in the lower courses of stone.

48. Stonework should be laid either with cement, or with cement-and-lime mortar, for damp places; while for dry situations, lime mortar may be used. Cement is always preferable, however, for general use.

In work that is to be pointed, no mortar should be placed within an inch of the front edges of the stone, as this saves raking out the joints preparatory to pointing. Sometimes slips of wood, just the thickness of the joint, are set on the edges of the lower course; in setting the stone, the superfluous mortar is pressed out and the stone rests on the wooden slips, which are removed when the mortar is hard.

Portland and Rosendale cements discolor most limestones and marbles, and some sandstones. By exercising care, the mortar may be kept from the face of the stone, and the joints

may be pointed afterward, with mortar that will not stain the stone. A cement made of plaster of Paris, lime, and marble dust, called *Lafarge* cement, is sometimes used for setting marble and limestone; it is claimed that this will not cause discoloration.

RUBBLE WALLS.

49. Rubblework is used for rough masonry, as in foundations, backing, etc., and frequently consists of common field stone, roughly dressed; but whenever possible, quarried rubble should be used, as better bedding can thereby be secured. Conglomerate and slate stones abound in many locations, and are cheap and durable, but do not cut easily. They are often used with good effect in walls with cut-stone or brick trimmings; or, when good lengths can be had, for rock-faced sills, lintels, and trimmings.

Fig. 18 represents a good rubble wall, the stones being bonded about every 4 or 5 feet, as shown at *a*; the largest

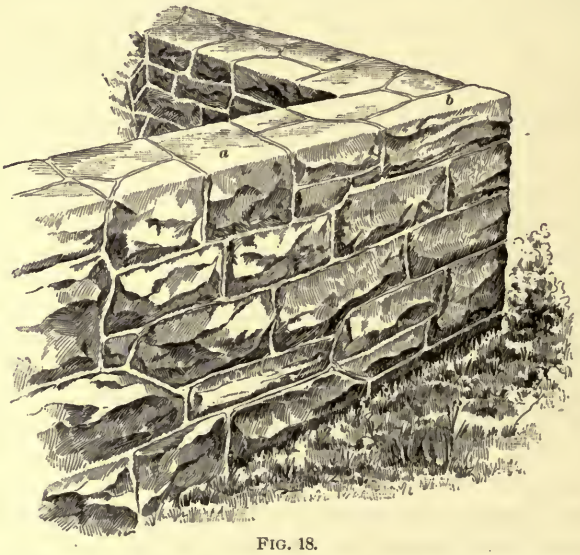


FIG. 18.

and best stones should be placed at the bottom, and at the angles, as indicated at *b*, laid up in alternate courses of

headers and stretchers. Such work is generally laid with beds and joints dressed but very little, the rough angles only being knocked off; the stones are set irregularly in the wall, the interstices being filled with spalls and mortar. If better work is desired, the joints and beds of the stonework should be hammer-dressed. The walls are frequently pointed with colored mortar, showing raised joints.

50. Fig. 19 shows a form of rubble masonry much used for country and suburban work. The *quoins*, or corner stones *a*, are hammer-dressed on top and bottom, and may

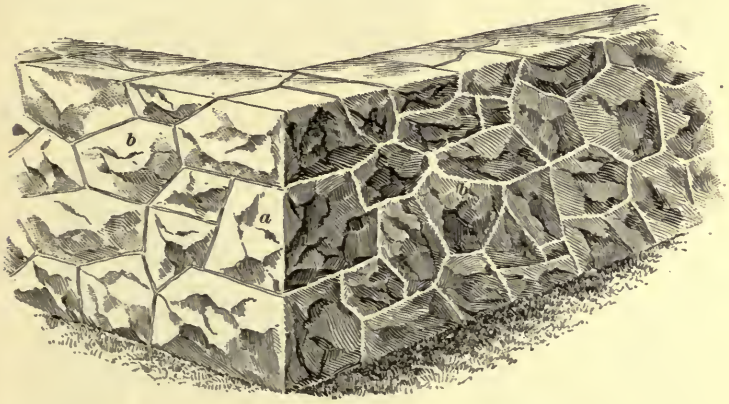


FIG. 19.

be either cut stone or rock face; the last harmonizes well when there is similarly dressed stone in the body of the wall. All the joints should be hammer-dressed, as shown at *b*, and no spalls should show on the face, while the mortar joints should not exceed $\frac{1}{2}$ inch to $\frac{3}{4}$ inch in thickness. This makes an effective wall, especially for country churches, lodges, and other small buildings; but the work is expensive, owing to the labor required in dressing the joints.

51. Small boulders and field stones are often used for walls in rustic buildings. An example is shown in Fig. 20. Such a wall should be quite thick, and it is well to use a backing of split stone, to better bond together the boulders.

52. Fig. 21 shows a rubble wall with brick quoins, or corners, as shown at *a*. In this case all the top and bottom

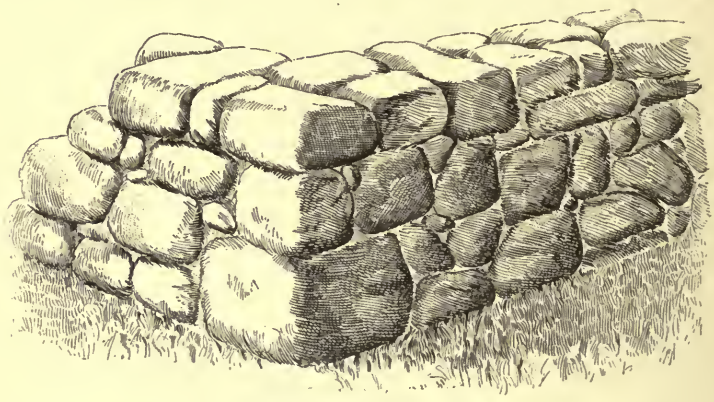


FIG. 20.

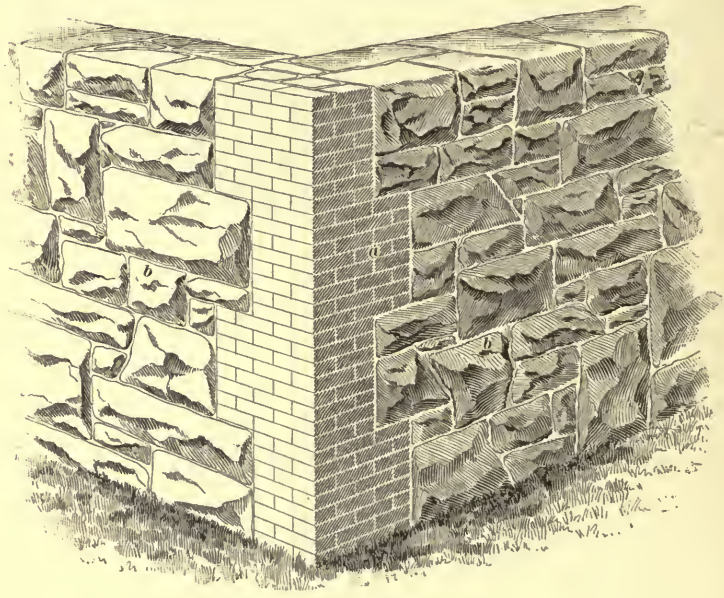


FIG. 21.

joints of the rubblework have *level* beds, as at *b*. This makes a very effective wall, and can be built quite cheaply

when the stone used splits readily, or can be laid on its natural bed, thus requiring but little dressing.

53. Coursed Rubble.—In walls of this sort, some effort is made to produce a coursed effect, using stone of random sizes; little or no attention, however, is paid to uniformity of height in the different courses. For such walls, the stones are generally roughly dressed by the mason before he begins work. Care should be taken to get as nearly parallel beds as possible, and to bring the face of each stone to a fairly even surface at right angles to the beds. The quoins, or corner stones, in coursed rubble are

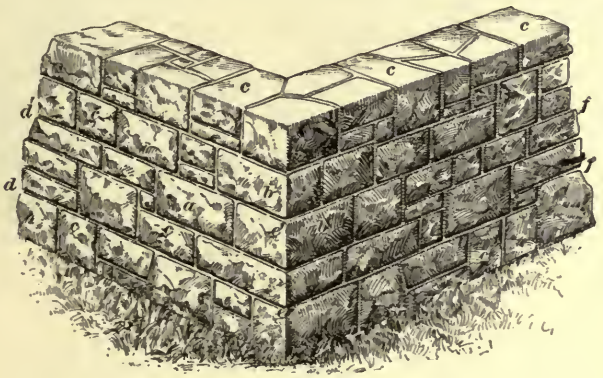


FIG. 22.

usually dressed and laid with more care than the remainder of the work, and also serve as gauge courses. Coursed rubble, when well built, makes a very solid wall, and is much used.

Fig. 22 represents a coursed rubble wall, *a* showing the rubblework; *b*, the quoins; *c*, the bond stones running through the walls; *d e f* and *d′ e′ f′*, two of the course joints.

ASHLAR.

54. When the outside facing of a wall is of cut stone, it is called **ashlar,** regardless of the manner in which the stone is finished. Ashlar is usually laid either in regular courses, with continuous horizontal joints, as shown in Figs.

23, 24, and 25, or in broken courses, without regard to continuity of the joints, as shown in Fig. 26. All ashlar should have straight and horizontal bed joints, and the vertical joints should be kept plumb. Failure to do this mars the effect of the work very materially.

55. **Coursed ashlar** is a class of stonework in which the pieces are uniform in size and the bed joints are continuous. When such stones can be obtained readily, this is not a very expensive kind of work. Pieces about 12 inches high, and

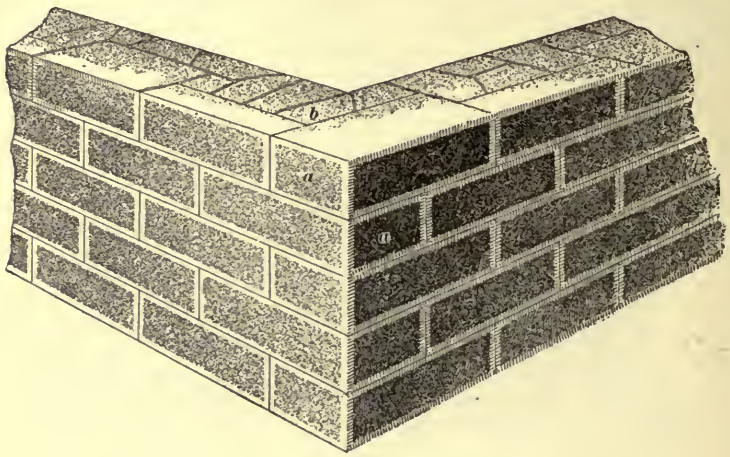


FIG. 23.

from 8 to 24 inches long, are probably the best, both as regards cost and ease of handling. If this stone is cut from 30 to 36 inches in length, with the end joints plumb over one another, the cost is proportionately increased. Fig. 23 shows this kind of work; *a* indicates the $12'' \times 36''$ ashlar, and *b* the backing, consisting of 12-inch rubble.

56. A good effect is produced by making the courses of two different heights, but cut in regular sizes, and having the vertical joints in alternate courses directly over one another. This class of work is shown in Fig. 24, in which *a* is a 14-inch course; *b*, a 6-inch course; and *c*, the backing. The latter may also be brick, as the ashlar can be well bonded into it. If the narrow band course *b* is cut with

rock face, or in some different way than the wide courses *a*, the appearance of the work is further improved.

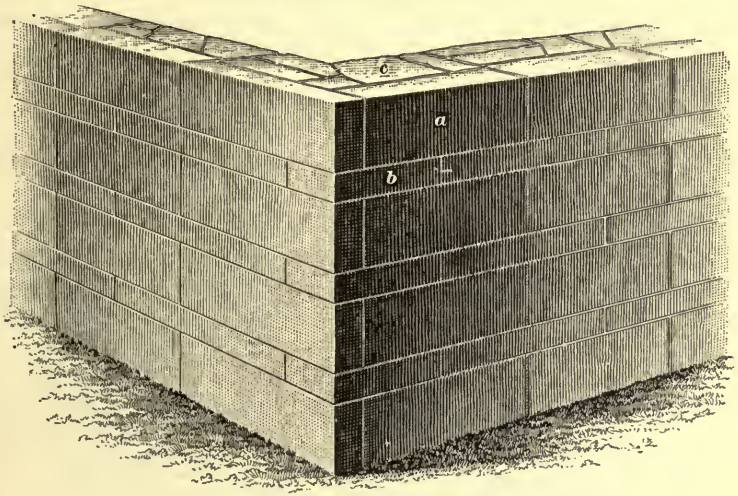


FIG. 24.

57. The stonework of many public and office buildings have rustic quoins and base or band courses, as shown in Fig. 25, where *a* indicates the quoins, having a 1-inch bevel,

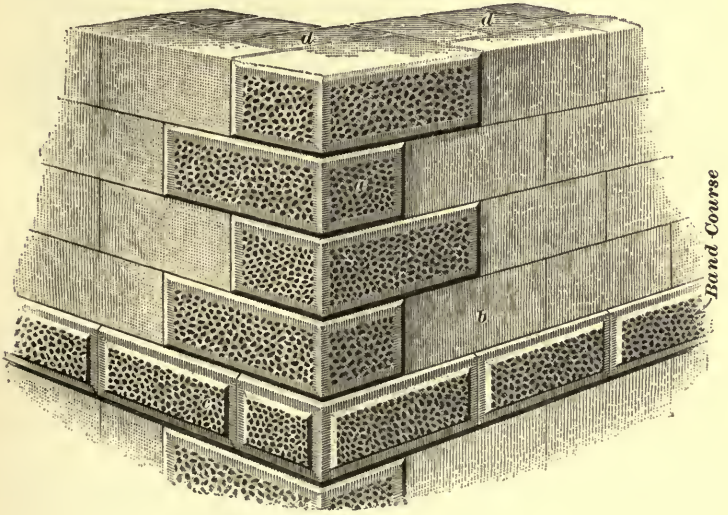


FIG. 25.

or chamfer, at the joints; *b*, the plain, rubbed, or tooled stones forming the face of the wall; *c*, the rustic band course, having a 1½-inch chamfer cut on it, so as to project beyond the quoins; and *d*, the stone or brick backing. This method of construction is very expensive, owing to the great amount of dressing required.

58. Broken Ashlar.—It is often found that stones of uniform size cannot be cheaply obtained, in which case, irregular sizes may be used, forming what is termed *broken ashlar;* by careful workmanship, a coursed effect may be produced with nearly continuous horizontal joints. Probably the great majority of stone buildings consists of this class of masonry. It generally takes a longer time to build broken ashlar than coursed work, and hence it is more costly, owing to the increased amount of labor required to

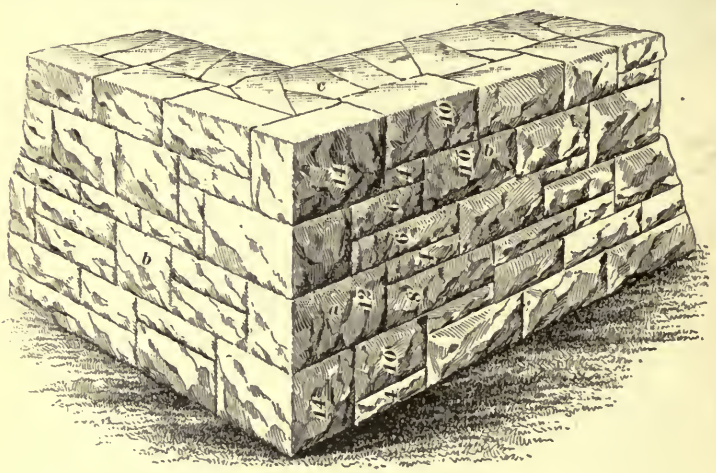


FIG. 26.

fit and lay the different sizes of stone. This kind of ashlar, when properly executed, presents a pleasing appearance. It is generally laid up as rock-faced work, but in some cases, it is tooled or hammer-dressed. It should have no horizontal joints more than 4 feet long, and several sizes of stone should be used. Fig. 26 shows an ordinary broken ashlar wall, 2 feet thick, the sizes of stone used being 4, 6, 8, 10, 12,

and 14 inches in height; *a* shows the quoins; *b*, the different sizes of ashlar; and *c*, the stone or brick backing.

Fig. 27 represents the same kind of a wall, using only

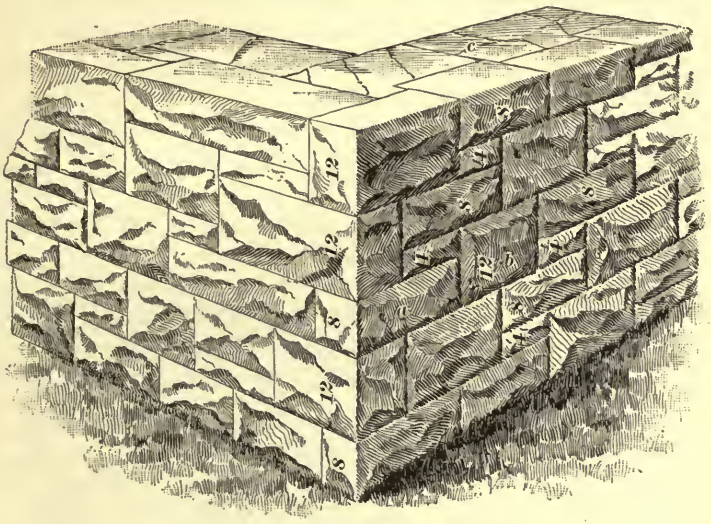


FIG. 27.

three sizes of stone, 4, 8, and 12 inches in height; *a* shows an 8-inch quoin; *b*, a 12-inch stone; and *c*, the backing.

59. Random Work.—Broken ashlar is often arranged as shown in Fig. 28, the courses being 18 to 24 inches high. This is called *random-coursed* work, for the reason that the stones have broken, or random, joints, and do not break joint directly over one another, as in coursed ashlar. Stonework of this kind is used very often for piers, and makes a strong wall, as all the stones bond well and the perpendicular joints are well broken.

In Fig. 28, *a* indicates the corner stones; *b*, the random ashlar; *c*, the horizontal joints in the stonework; and *d*, the stone or brick backing.

60. Laying out Ashlar.—If ashlar in regular courses and sizes is to be used, drawings should be made showing each different-sized stone, the heights of the courses, and

other necessary details. The plans for public and office buildings, etc., usually show every stone, unless broken ashlar is used, in which case it is only necessary to show the quoins and jambs on the drawings, together with enough of the ashlar to indicate the character of the work desired. It is almost impossible to carefully follow a drawing showing all the stones laid as broken ashlar.

61. Thickness of Ashlar.—All kinds of ashlar are usually backed with stones not as carefully finished as those

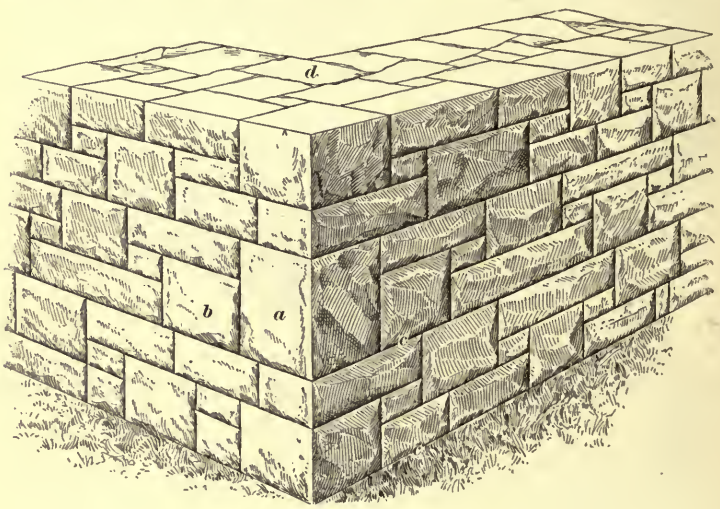


FIG. 28.

on the face. When the ashlar does not exceed 12 inches in height, the thickness varies from 4 to 8 inches, usually the latter. A much better bond is formed when one stone is 6 or 8 inches thick, and the other 4 inches, than when there is a uniform width of, say, 6 inches. When ashlar is laid in low and high courses, the lower one should be at least 8 inches, and the higher one 4 inches, thick; each stone in the courses, when more than 18 inches high, should have an iron anchor extending through the wall.

62. Backing.—Both stone and brick are used for backing, but brick is, in most cases, the cheapest, and, hence,

most extensively used. It has, in addition, the advantage that in dry climates the plastering may be applied directly to the brickwork; while if stone backing is used, it usually has to be plugged and furred for the lathing. When brick is used for ashlar backing, the joints should be as thin as possible; if lime mortar is used, it is best to add some cement, to prevent shrinkage of the joints. No ashlar wall should have a brick backing less than 8 inches thick. When a hard, laminated stone, with flat, parallel beds, is obtainable, it should be used, as it is considered to be a stronger backing than brick. Irregular rubble walls should not be used for anything higher than 2 or 3 story dwellings, unless the walls are made at least one-fourth thicker than when brick backing is used. All backing, whether of brick or stone, should be carried up at the same time, and built in courses of the same thickness as the ashlar. This is shown at *a* in (*a*) and (*b*), Fig. 29.

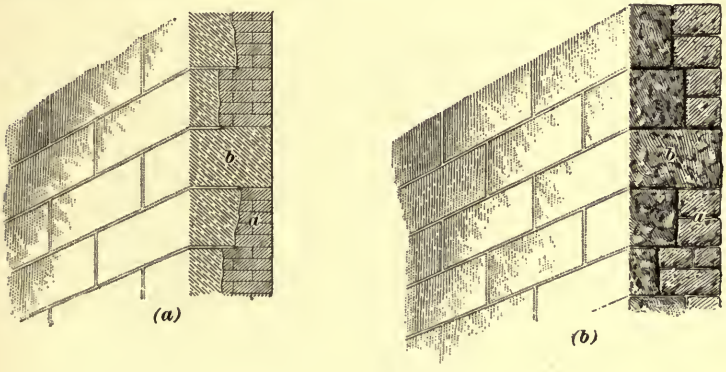


FIG. 29.

When the courses are not over 12 inches high, they are usually bonded sufficiently to the backing by making the stones of various thicknesses, and by having one through bond stone to every 10 square feet of wall, as shown at *b* in (*a*) and (*b*), Fig. 29.

63. Very often ashlar is only from 2 to 4 inches thick, especially with marble, and some sandstones. In such cases, each piece of ashlar should be tied to the backing by at least

one iron clamp, or anchor, similar to that shown in Fig. 30; while if the stones are more than 3 feet long, two anchors are generally used. All iron clamps or anchors should be either galvanized or dipped in hot tar or asphalt, to prevent the formation of rust on them.

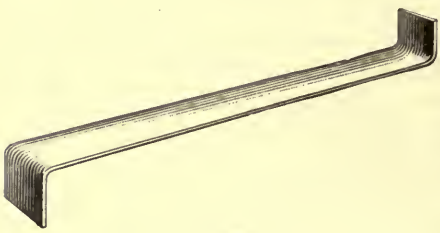


FIG. 30.

Belt courses should also be laid about every 6 feet in height, extending 8 inches or more into the wall, to give support to the ashlar. When a wall is faced with thin ashlar, the effective bearing strength is only that given by the thickness of the brick or stone backing, the facing not being relied on for that purpose.

BOND STONES AND TEMPLETS.

64. Strictly, these are not ashlar, but as more or less dressing is necessary on them, they are here mentioned.

In most of the larger cities, the building regulations require **bond stones** in brick piers of certain sizes. Only strong stones, such as granite, bluestone, and hard trap rock, should be used, and should be cut the full size of the pier. The course of brick underneath should be brought to an exact level to receive the stone; otherwise, the weight above may cause it to crack, or become displaced.

65. **Templets** are the bearing stones placed under the ends of beams and girders, and serve to distribute the weight more evenly on the wall. They should always be made of a hard and tough stone; the usual rule is that the thickness of the stone should be one-third of the smallest surface dimension, except when very large stones are used; but the *least* thickness should be 4 inches. It is better to have the templets too large than too small. When a wooden girder rests on a templet, it is well to place a flat stone

above the end of the girder, so that the wall will rest on the stone and not on the wood. This is advisable for the reason that when the wood shrinks the settlement may cause cracks in the wall.

QUOINS AND JAMBS.

66. Quoins are the corner stones of a wall, and are often dressed differently from the other stones, in order to make them more prominent, as, for example, those shown in Fig. 25. Quoin stones should always be equal in size to the largest stone used in the wall; otherwise, the effect of strength and solidity that they are intended to produce will be lost. Sometimes the quoins in a rubble-stone wall are built of brick, as shown in Fig. 21.

67. The stones in the sides of a door or window opening are called **jamb stones.** The alternate ones should extend through the width of the wall, to insure a good

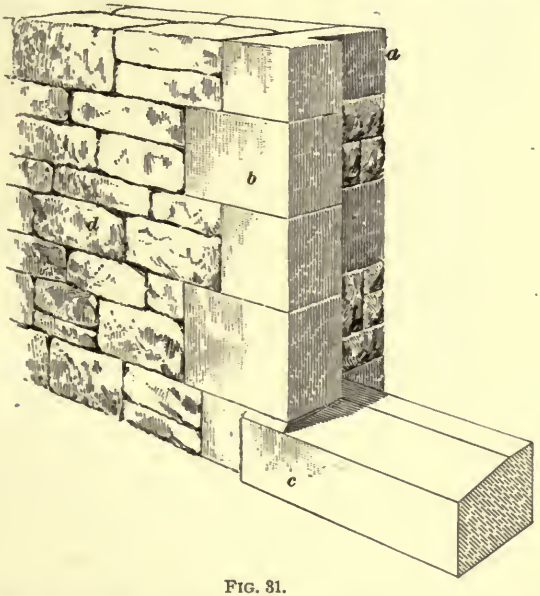


FIG. 31.

bond. Fig. 31 represents cut-stone jambs in a rubble wall; *a* shows the jamb stones bonding into the wall transversely;

b, those bonding longitudinally; *c*, the stone window sill; and *d*, the rubble wall.

68. Occasionally, when stone piers or pilasters are built on the outside of a building, the windows are recessed so that the sills and lintels will not have as great a projection. This is shown in Fig. 32, in which *a* shows the lintel; *b*, the sash; and *c*, one of the jamb stones.

Jambs and quoins are often finished with a draft, or angle line, especially when the softer stones are used. Fig. 33

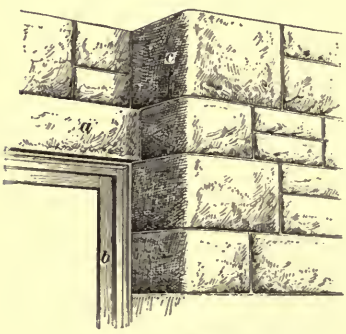


FIG. 32.

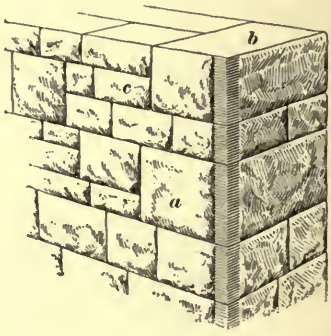


FIG. 33.

shows this method of finishing; *a* indicates the quoin or jamb stone, as may be the case; *b*, the angle draft; and *c*, the broken ashlar wall.

TRIMMINGS.

69. The term *trimmings*, as generally used, includes moldings, belt courses, sills, caps, and other cut stone (except ashlar) used for ornamental purposes.

The stones for such work should be of good quality, having the beds closely dressed and the ends square and properly matched. The faces may be pitched off, but all washes, soffits, etc. should be cut or rubbed. When a brick building is trimmed with stone, great care should be taken to have the trimmings set properly, without having to split

the courses of brick below or above; such a procedure would spoil the appearance of the building.

70. Washes and Drips.—The tops of all cornices, belt courses, etc. should have an outward pitch from the walls, as

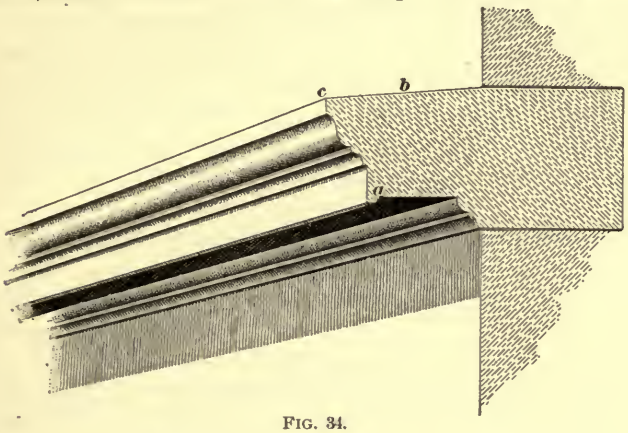


FIG. 34.

shown at *b*, Fig. 34. If the top is level or slopes inwardly, rain will collect, and in time will cause the disintegration of the mortar in the adjacent joints, and will finally penetrate the wall. The beveled surfaces are called *washes*. On the under side of the cornices, etc., *drips* should be made, to prevent rain from flowing down the faces of the walls. At *a*, Fig. 34, is shown the drip; at *b*, the wash of the cornice; and at *c*, the stone cut to a sharp angle, to shed part of the water from that edge.

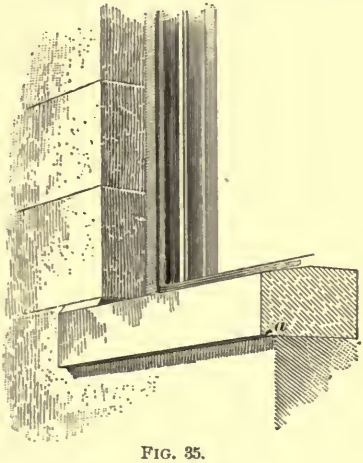


FIG. 35.

Window sills should also have a drip cut in them, as shown at *a*, Fig. 35, to keep the walls below from becoming discolored by dirt washed off the sills by rain.

LINTELS.

71. A **lintel,** often called a *cap*, is a stone supporting the wall over a door or window opening; and, as it is to resist bending stress, should be a strong, tough stone, having an ample cross-section. The ends of stone lintels should not be built into the walls more than is necessary to give sufficient bearing; 4 to 6 inches at each end is the usual allowance. There should be a little play allowed at each end, so that, if the walls on either side settle unevenly, the lintels can yield slightly without cracking.

72. Strength of Lintels.—A lintel acts as a beam, and hence the ordinary beam formulas will apply. For uniformly loaded beams, the breaking load is found as follows:

Rule.—*Multiply twice the breadth in inches by the square of the depth in inches, and also by the proper constant from the table. Divide the product by the span in feet; the quotient will be the breaking weight for a uniformly loaded beam.*

Expressed by a formula, this rule is:

$$\frac{2\,b\,d^2\,A}{L} = W,$$

in which
b = breadth in inches;
d = depth in inches;
L = span in feet;
A = constant;
W = breaking load in pounds.

If the weight is concentrated at the center, the breaking load is $\frac{1}{2}W$ instead of W.

The value of A is, for bluestone, 150; for granite, 100; for limestone, 90; for marble, 120; for slate, 300; for sandstone, 70.

This formula is practically the same as that in Art. **122,** *Masonry*, § 7, the only differences being in the value of the constant A, and in its application to distributed instead of concentrated loads.

73. When the weight on a lintel consists of a dead load, such as masonry, which is not liable to shocks, one-sixth of the breaking load may be taken as safe. If, however, the lintel is subject to live loads of any kind, not more than one-tenth of the breaking load should be taken. In such cases it is better to avoid the use of stone lintels, unless reinforced by angles or beams.

As an example, let it be required to find the breaking load of a bluestone lintel 10 inches wide, 24 inches high, and 7 feet long between supports, and uniformly loaded. Using the formula,

$$W = \frac{2 \times 10 \times 24^2 \times 150}{7} = 246{,}857 \text{ pounds.}$$

Taking one-sixth of this, gives 41,143 pounds as the safe uniformly distributed load.

74. Relieving Lintels.—Often when a long lintel is needed over an opening, the stonework above the lintel is arranged as shown in Fig. 36, in which *a* is the lintel, and *b*

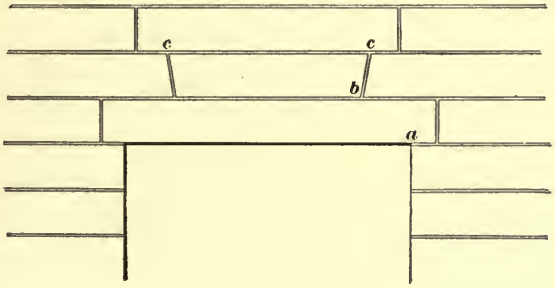


FIG. 36.

the stone above it cut with two diagonal joints, as at *c*. In this way, some of the load is taken off the lintel and transferred to the wall on both sides of the opening.

If a lintel extends through the wall, and is not supported by angles or beams, the strength may be increased, if the stone is stratified, by cutting it in such manner that the layers will set on edge. Many old Roman and Greek structures show lintels so cut.

75. When considerable weight rests on a stone lintel, a brick relieving arch (see Art. **269,** *Masonry*, § 7) may be used, but, unless much skill is exercised, this detracts from the appearance of the building, if the arch extends through the entire thickness of the wall. To avoid this result, if stone of sufficient depth cannot be used, the lintel may be strengthened by the use of iron beams or angles. When the lintel is of moderate length, it is sufficient to use a piece of angle iron, as shown in Fig. 37, in which *a* is the stone lintel; *b*, the angle, which should have its longer side vertical; *c*, a wooden beam to which the interior woodwork is nailed; *d*, the brick wall; and *e*, the window reveal.

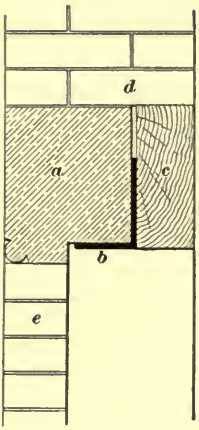


FIG. 37.

76. When the width of the opening is considerable, stone lintels should be supported on **I** beams. If only the weight

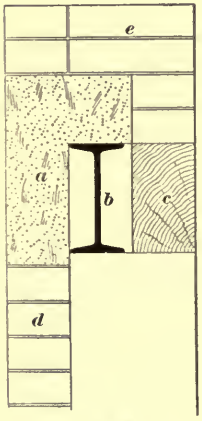


FIG. 38.

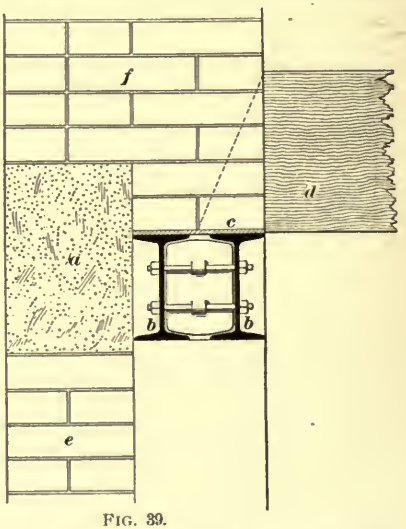


FIG. 39.

of the lintel and wall is to be carried, a single **I** beam may be used, as shown in Fig. 38, in which *a* represents the stone

lintel; *b*, the I beam; *c*, the wooden beam to which the wood finish is attached; *d*, the reveal; and *e*, the brick wall.

When, in addition to the walls, the floorbeams over openings must be carried, it is best to use two I beams, as shown in Fig. 39, in which *a* is the stone lintel; *b*, *b*, the I beams, held together by bolts and separator; *c*, an iron plate on which the wall rests; *d*, a floorbeam; *e*, the window reveal; and *f*, the brick wall.

When it can be avoided, it is best not to support the weight of a wall upon both stone and steel or wood beams, as the deflection of each material is different, making it practically impossible for each to carry its proper share of the load. The weight should preferably be borne by the steel beams alone.

77. Built-Up Lintels.—It is sometimes necessary to use a stone lintel 10 or 12 feet long, which is difficult to obtain in a single piece. In such a case, the lintel may be

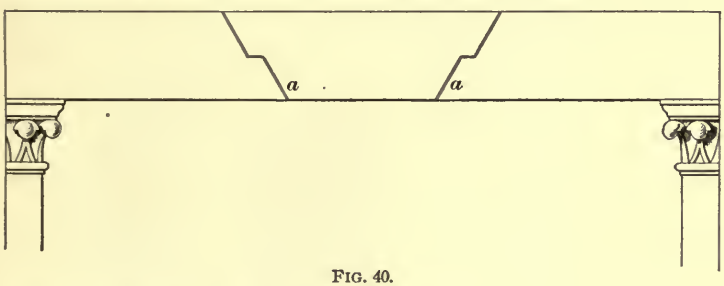


FIG. 40.

made in sections. At least three stones should be used, and the joints should be cut as shown at *a*, Fig. 40. When cut in this manner the stones are apparently self-supporting. The end pieces may be built into the wall for a considerable length, so as to act as cantilevers supporting the middle section. If such long lintels are used, it is better to carry them on I beams, as shown in Figs. 38 and 39.

SILLS.

78. Sill is the name given in mason work to the stones forming the bottom of the window and door openings in stone or brick walls.

Slip sills are made just the width of the opening, and are not built into the walls, but put in place after the frame is set. Slip sills are cheaper, but do not look as well as lug sills; besides, there are exposed vertical joints at the ends, into which water will penetrate. Any settlement of the masonry is not likely to break a slip sill, and hence they are often used in the lower parts of heavy buildings.

Lug sills have flat ends, or *lugs*, built into the wall. They should not enter the walls over 4 inches, and should be bedded on mortar only, at the ends, while being set. If settlement occurs, and a sill is bedded solid, it would probably be fractured at the jamb line, as the pier or side walls would be very likely to settle more than the wall under the opening. The joints under the sills should be filled when the finished walls are cleaned down.

79. All sills should have a bevel, or wash, of about 1 inch per foot, extending to the back of the reveal, as shown in Fig. 41. They sometimes have a straight, beveled surface

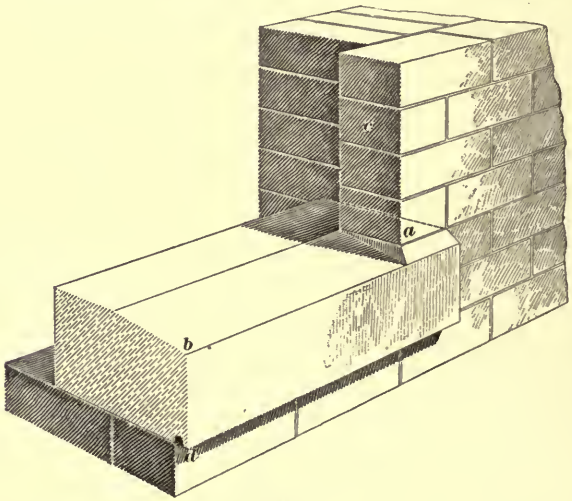


FIG. 41.

the full length of the sill, the bricks being cut to fit the stone. This, however, is not good practice, as such construction permits water, running down the jamb, to enter

the joint between the brick and stone; the sloping upper face also forms an insecure bearing for the wall resting on it. In Fig. 41 is shown the proper method of cutting the surfaces; *a* indicates the flat end of the lug sill, carrying the brickwork reveal *c*; *b* shows the bevel, or wash; and *d*, the drip.

COPINGS.

80. A wall having no roof covering should be capped by a wide stone called the **coping.** Terra cotta is occasionally used for this purpose, and sometimes tin. The upper surface of the coping should be pitched, as shown at *a*, Fig. 42,

FIG. 42.

and should have a drip on the under side, as shown at *b*. The width of the coping should be about 3 or 4 inches more than that of the wall. Horizontal coping stones are often clamped together at the ends to prevent their becoming displaced.

81. Gable copings do not need to be pitched, but should project about 1½ inches beyond the face of the outside wall, and should have a sharp outer edge to shed rain, so that it will not flow down the wall. The coping should be well

anchored, either by bond stones or by long iron ties. A form of coping that is considerably used is shown in Fig. 43,

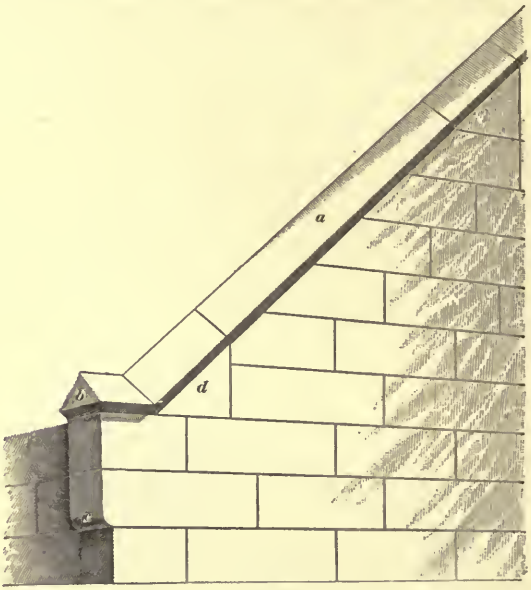


FIG. 43.

in which *a* is the coping; *c*, the corbel; and *b*, the bottom stone, sometimes known as the *kneeler*, which should always be well bonded into the wall.

It is well to have long pieces of coping, so as to have as few joints as possible; a common length is 6 feet. A short piece, cut as shown at *a*, Fig. 44, should be inserted at intervals to securely bond the coping to the wall. In some cases the part resting on the wall is cut in steps, so that each stone has a level bearing, but this is objectionable, on account of the increased number of joints.

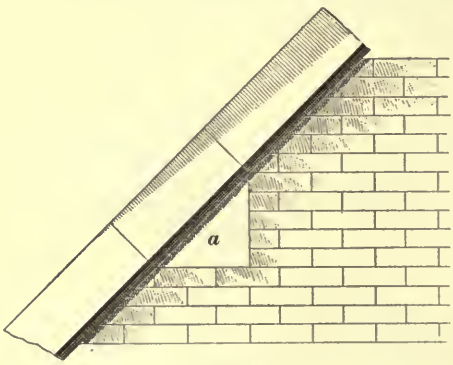


FIG. 44.

COLUMNS AND ENTABLATURES.

82. When possible, it is best to have the shaft of a column formed in one piece, irrespective of length—that is, a *monolith.* All the columns in the later portion of the Capitol at Washington are marble monoliths, quarried in Maryland. For a good class of work, if the column is not over 8 feet in height, the shaft is generally so cut, with the cap and base separate.

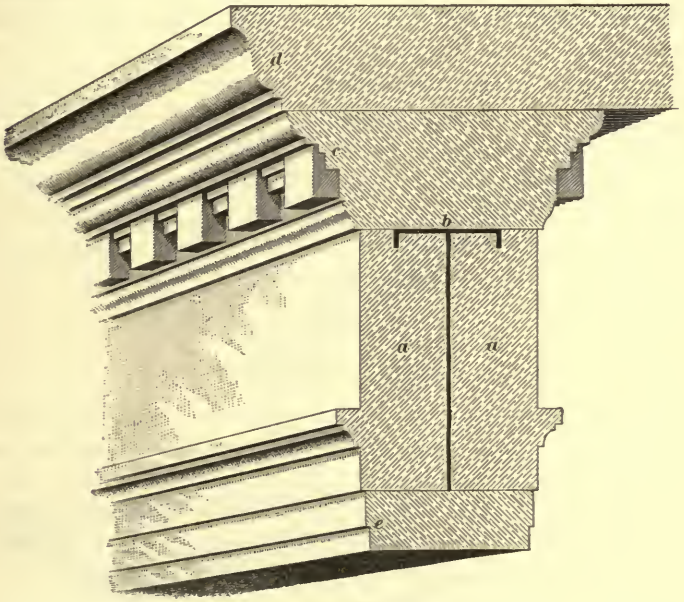


FIG. 45.

When a column is to be formed of several pieces, the stones composing the different parts should be very carefully cut, having the abutting surfaces between the cap, base, and shaft perfectly plane and perpendicular to the axis of the column, in order that the pressure may be evenly distributed over the entire surface of the joints. For the latter, nothing but cement mortar should be used, which should not be allowed to come within $\frac{3}{4}$ inch of the edge of the joint, in order to prevent spalling the edges of the stones.

If the column is built against a wall, forming what is

called a *pilaster*, the cap and base should be bonded to the wall, either by extending them into it, or by securing them to it by galvanized-iron clamps, or anchors.

83. An **entablature** is that part of the structure spanning a porch, or entrance, opening, and supported by columns. All the stones composing the entablature should be well tied together with clamps and anchors, particularly at the outer angles. Porch cornices are sometimes tied to the main structure by long rods enclosed in the mason work, so as to prevent the porch from settling away from the building.

An example of an entablature is shown in Fig. 45, which represents the cornice of a porch. In this, *a*, *a* show the two facial stones forming the inside and outside of the entablature; *b*, the iron clamp, or anchor, holding them together; *c*, the lower portion of the cornice, showing the *dentils;* *d*, the upper part, showing the *corona;* and *e*, the bottom member of the architrave, or lower portion of the entablature.

STONE STEPS.

84. A hard stone, such as granite or bluestone, should be used for steps; but for private residences, where the

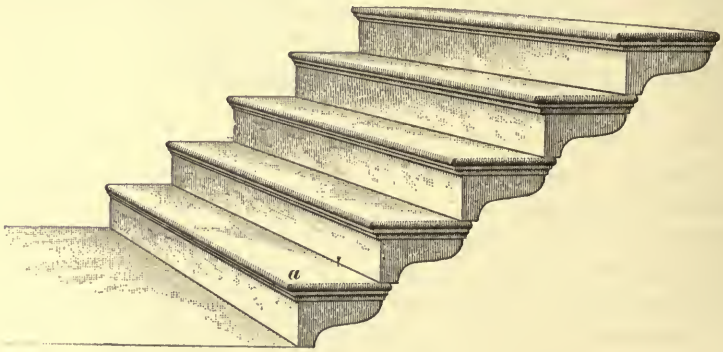


FIG. 46.

wear is not great, limestone or a fairly hard sandstone may be used. Outside steps should be firmly supported at each end, and if more than 6 feet long, should also have a center

bearing. Each step should overlap the one below at least $1\frac{1}{2}$ inches, and should have an outward pitch of about $\frac{1}{8}$ inch. Steps having a nosing, as shown at *a*, Fig. 46, make a good appearance, but are much more expensive than the ordinary ones.

85. Stone stairs are sometimes made with but one end supported. This end is built solidly into the wall, and each step is carried on the next lower one. This construction is shown in Fig. 47, in which *a* represents the landing rabbeted

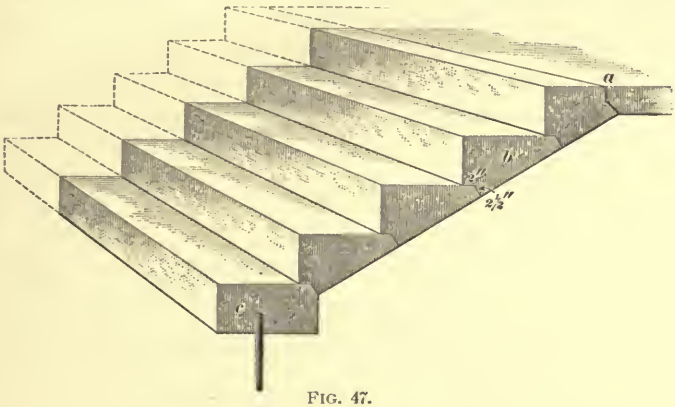


FIG. 47.

into the tread of the top step; while *b* shows the manner in which each step is cut and supported by the lower. To be safe, the bearing dimensions should not be less than here shown. The bottom step should be firmly held in place by dowels set into the floor (as shown at *c*), as this step must sustain the thrust of the whole flight of stairs. The stone blocks forming the steps are usually cut in the triangular cross-section shown, which method of cutting gives a good appearance to the soffit, or ramp, of the stairs.

86. Iron staircases are very extensively used in fireproof construction; the treads, and sometimes the risers, are usually marble slabs. Slate, being cheaper, is also considerably used. Staircase railings, for stairways having stone or iron steps, are often elaborately finished, and are generally made of iron, doweled into the ends of the steps.

STONE ARCHES.

87. Stone arches are generally used in both stone and brick structures, over door and window openings, for porches, etc. They are also erected over streams and roads for highway and railway bridges and aqueducts. Stone arches of long span are not as frequently built now as formerly, iron and steel having been very largely substituted for stone. In some ways, a stone arch is not as satisfactory as a brick one. Being composed of a few large pieces, instead of many small ones—as is a brick arch—the bond is not so perfect; and consequently, of the two, the stone arch is somewhat more liable to settle and crack.

The amount of masonry in heavy piers, etc., can, without injuring the stability of the structure, often be considerably diminished by the use of arches, provided the stone and the footings are capable of carrying the increased load. The pressure on the soil may, if necessary, be decreased by using inverted arches. (See Arts. **91–95,** *Masonry*, § 7.)

88. The principal parts of an arch are as follows: The *abutments* are the piers from which the arch springs, as at

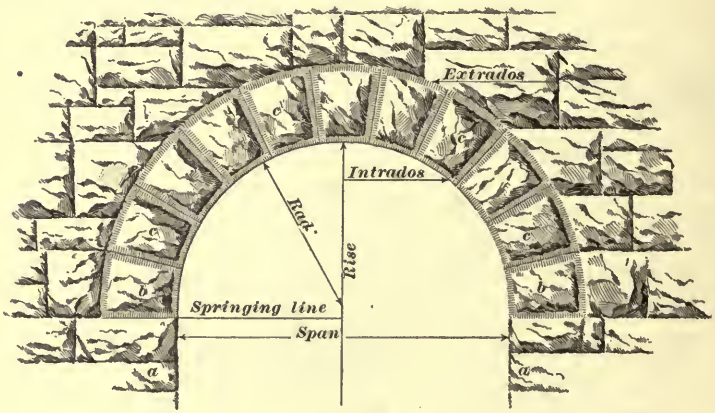


FIG. 48.

a, Fig. 48. The inner edge of the top of the abutment is called the *springing line;* the stones resting on the

abutments, shown at *b*, are called *skewbacks*. The arch itself consists of wedge-shaped stones, called *voussoirs*, or *ring stones*. These are sometimes of varying sizes, but for the same arch are generally made as nearly uniform as possible; the depth (back into the wall), however, may vary as much as may be necessary for proper bonding. The voussoirs are shown at *c*. The ring stones between the keystone and the skewbacks are collectively known as the *haunches* of the arch. The masonry resting on the arch ring, from the piers to a horizontal line touching the highest point of the upper curve, form the *spandrels*. The under surface of the arch is called the *soffit*, and a line representing the curve of the soffit is the *intrados;* the one parallel to it at the outer end of the voussoirs is called the *extrados*. The *span* of an arch is the distance between the abutments; and the *rise* is the extreme vertical height from the springing line to the intrados.

89. In building construction, it is not customary to determine the proportions of arches of small span by calculation. The appearance is often the controlling factor in designing such arches. But when the arches are of considerable span, the position of the *line of resistance* should be determined. As that is somewhat beyond the scope of this section, merely the conditions necessary for stability will be here mentioned.

In relation to arches for engineering purposes, the well known authority, Professor Rankine, says: "The best course in practice is to assume a depth for the keystone based on the dimensions of good existing examples." This statement holds good in connection with the construction of the arches which an architect ordinarily has to design.

90. Having fixed the depth of the keystone, the voussoirs are all made the same height, in arches of small span, while in longer ones the ring stones vary in depth, increasing gradually from the crown to the skewbacks, so as to preserve a uniform pressure on the stones as the load becomes greater. The resistance to crushing of any kind of

stone may be readily determined, and a large margin of safety must be allowed over the greatest pressure to which it will be subjected in the arch.

91. To insure the stability of an arch, there are two conditions, besides the one just mentioned, which must be satisfied. One is that the pressure shall not cause the opening of the joints; the other, that the direction of the pressure shall not be such as to cause one ring stone to slide on another.

In order to prevent rotation on the edge of any stone, the line of pressure—through which the load is assumed to act—must not be above or below the arch ring at any point, but must cut the abutting surfaces of the stones as near as possible to the center of the joint, and always within the middle third of the arch, so as to prevent the opening of the joints. To obviate the liability of sliding at any joint, the pressure tending to move one stone on another must not be sufficient, nor in such direction as to overcome the friction between the surfaces.

These requirements are met by making the arch ring of proper depth, and generally do not need to be determined theoretically for small arches.

92. Flat arches—those having but little rise—give way by breaking the four parts, opening at the crown of the intrados and at some joint on the extrados. When a flat arch breaks, the two upper parts fall inwards and press the lower parts outwards. In pointed arches, the reverse is the case, the lower portions tending to fall into the opening, and to force the upper parts outwards.

KINDS OF ARCHES.

93. Arches are frequently named from the curve of the intrados, as *semicircular*, *segmental*, *semielliptic*, *pointed*, etc. The *semicircular* arch is, as its name indicates, one whose intrados is a half circle. The *segmental* arch is one in which

the intrados is generally an arc of large radius, less than a semicircle. Sometimes the curve is composed of arcs of two or three different radii, in which case it is termed a *three* or *five centered* arch. The upper part of such an arch has a long radius, while the portions near the springing line have short and equal radii. This arch is nearly elliptic in form, and is often so known. The true ellipse is also used, an example being given in Fig. 55. Examples of segmental and three-centered arches are given under the heading "Brick Arches," *Masonry*, § 7. The *pointed* arch has its intrados formed of two arcs of equal radius, intersecting at the crown. The *equilateral* pointed arch is one in which the radii of the intrados are equal to the span, as shown in Fig. 51. There are numerous other forms of arches, but it is unnecessary to describe them all, on account of the general similarity between them and those already mentioned.

When the springing line of an arch is below the center, as shown in Fig. 48, the arch is said to be *stilted*, the distance from center to springing line being the *stilt*.

94. A stone arch frequently built is the one shown in Fig. 48. In this case the arch ring is of equal depth all around, and the voussoirs are all of the same size; the dressing is rock faced with pitched joints. Sometimes the voussoirs have a margin draft, as shown on *b* and *c*.

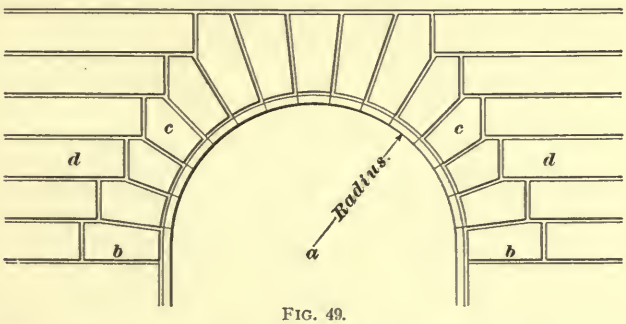


FIG. 49.

95. Arches that are used in coursed ashlar are often built as shown in Figs. 49 and 50. In each of these, *a* is

the center of the arch; *b*, *b*, the springing line; *c*, *c*, the ring stones; and *d*, *d*, the coursed stonework. Arches of this description are more expensive to execute than those in

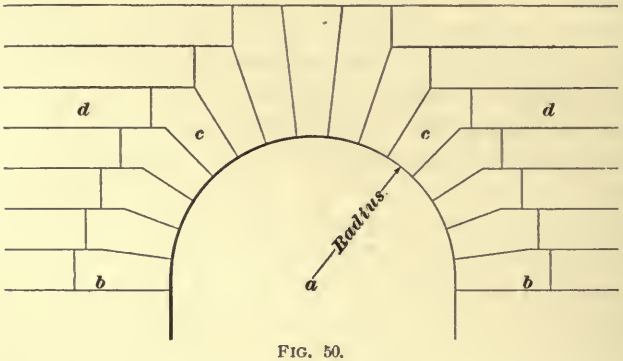


FIG. 50.

which the intrados and extrados are concentric, on account of the greater number of patterns required, the increased quantity of stone needed, and the work necessary to properly dress the voussoirs.

96. Fig. 51 gives an example of a *Gothic*, or pointed equilateral arch, with the intrados and extrados concentric.

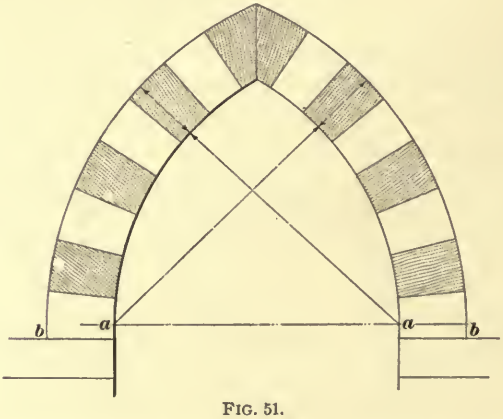


FIG. 51.

In this illustration, *a*, *a* are the centers from which the arch is struck, and *b*, *b* is the springing line.

97. Fig. 52 shows an arch having the intrados semicircular and the extrados pointed. Such arches are found in Venice, and are sometimes termed *Venetian Gothic* arches. At *a* is the center for the semicircular intrados; at *b*, *b* are the centers for the extrados, or pointed arch; and at *c*, *c* is the springing line.

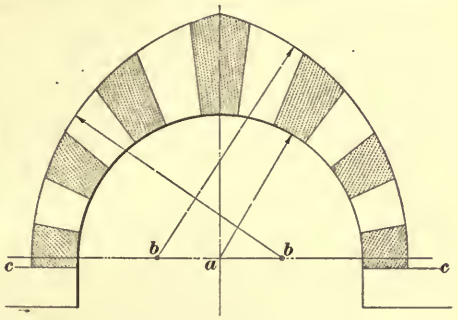


FIG. 52.

98. The *horseshoe*, or *Moorish*, arch is represented in Fig. 53. The Alhambra, at Granada, Spain, has some of

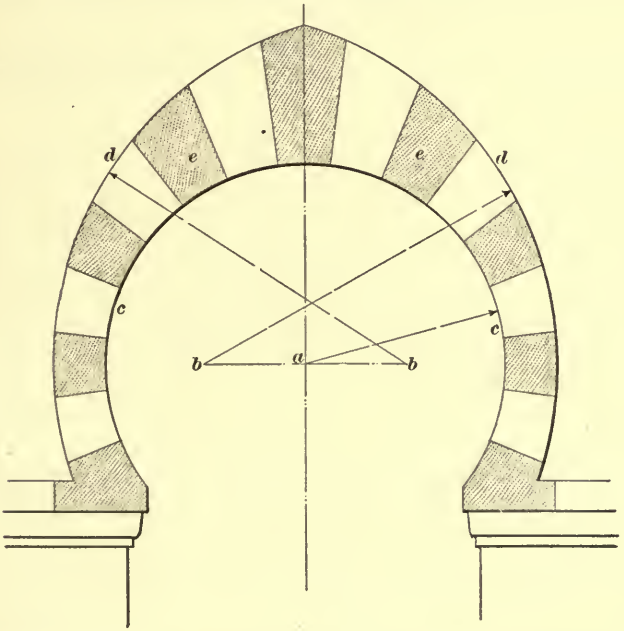


FIG. 53.

the best examples of this arch. Sometimes it is built with the intrados and extrados concentric, and also with the

intrados having a horseshoe form, and the extrados a pointed form. The example given shows the latter method of construction. At *a* is shown the center for the horseshoe intrados; at *b*, *b* are the centers for the pointed extrados of the arch; *c* indicates the soffit of the horseshoe arch; *d*, the upper side of the arch ring; and *e*, the voussoirs. In all horseshoe arches the center is stilted far above the springing lines, to produce the required effect.

99. Arches having an elliptical or oval form, or pointed in the center and elliptical near the springing joints, are often used in architectural work. These may be formed either of true elliptic curves, or of 3 or 5 centered circular arcs. Very flat elliptical arches are not suitable for any considerable span, and, if built, should have large piers or abutments; or beams may be placed above the arch, to relieve it of some of the load.

The method of finding the direction of the joints in a false elliptical arch is shown in Fig. 54. The construction of the

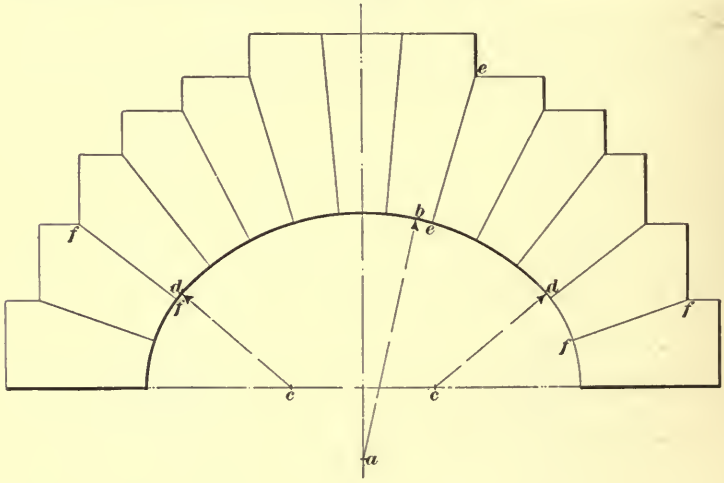


FIG. 54.

ellipse is similar to that given under the heading, "Inverted Arches," *Masonry*, § 7. The radius for the middle of the arch is *a b*; the radii for the two haunches are the lines *c d*.

The joints of the voussoirs in the central portion are drawn with a as a center, as at $e\,e$, etc.; and the joints for the haunches are drawn with c, c as centers, as at $f\,f$, etc.

100. A method of finding the voussoir joints in a true elliptical arch is given in Fig. 55. This shows d^1, d^2, d^3, d^4,

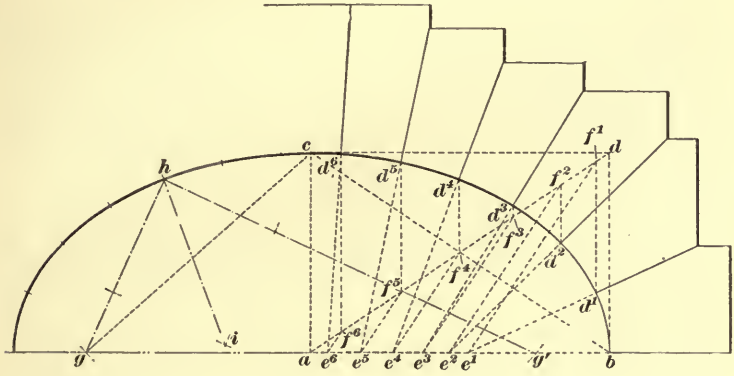


FIG. 55.

d^5, and d^6 as the points through which it is desired to draw the joints. Draw tangents to the ellipse at the points b and c, intersecting at d; also, the lines $a\,d$ and $b\,c$; draw from d^1, d^2, d^3, etc., lines intersecting $a\,d$ at f^1, f^2, f^3, etc. From these points, draw lines perpendicular to $b\,c$ intersecting $a\,b$ at e^1, e^2, e^3, etc.; then lines drawn through $e^6\,d^6$, $e^5\,d^5$, etc. will be normal to the curve and give the required joints.

Another and simpler method to find the direction of the joints is as follows: Find the foci of the ellipse by striking arcs from c with $a\,b$ as a radius, cutting the major axis at g and g'. Let h be the point where the direction of the joint is to be found. Draw $g\,h$ and $g'\,h$, and bisect the angle $g\,h\,g'$, as at $h\,i$; then $h\,i$ is the direction of the joint at h.

101. The flat arch is very common in architecture, but is not a strong construction. To be self-supporting it must

be of such a size that a segmental arch of proper radius and sufficient depth can be drawn on its face, as shown in Fig. 56 by the dotted lines *a*, *a*. This arch should have a radius equal to the width of the opening—which in this case is 4 feet—while the limiting width for an arch of this description should not be over 5 feet. The keystone should

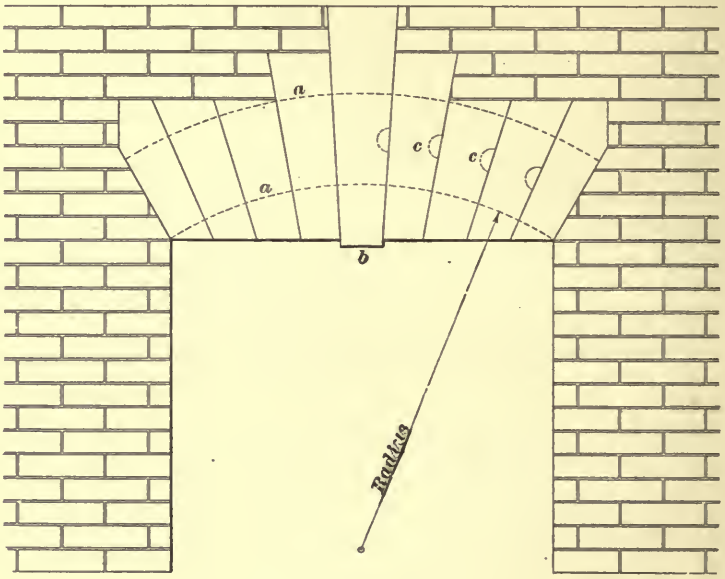


FIG. 56.

project about an inch below the soffit of the arch, as indicated at *b*, in order to more tightly wedge together the voussoirs. The strength of this arch may be increased by notching one stone into the next, as shown at *c*, *c*; or dowel-pins are sometimes used to bind the stone together.

102. When an arch is so flat as to have practically no rise, it should be cut out of one piece of stone, being really a solid lintel with false joints cut on its face, as shown at *a*, *a*, Fig. 57. The ends of this lintel should have a bearing on the wall of 4 or 5 inches, as indicated by the dotted

lines at *b*, *b*. If the walls are of brick, about 2 inches of the front of the stone may be cut away and faced with brick.

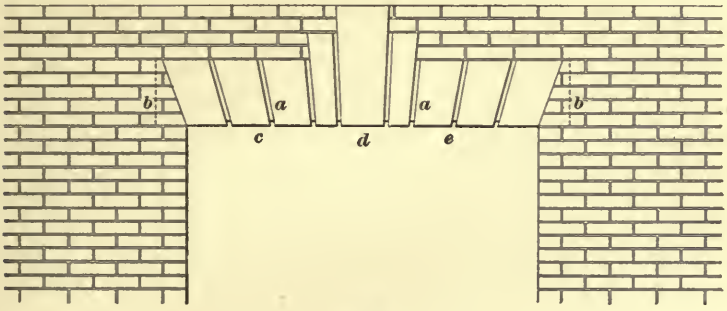


FIG. 57.

If this method is too costly, the lintel may be cut in 3 pieces, as shown at *c*, *d*, and *e*, and supported by a heavy angle bar, as described under "Lintels."

103. Rubble Arches.—For rough purposes, arches are sometimes built of rubble, as shown in Fig. 58, in which *b* represents the wall carried by the rubble arch, the ring stones of which, as *a*, should be narrow and roughly dressed

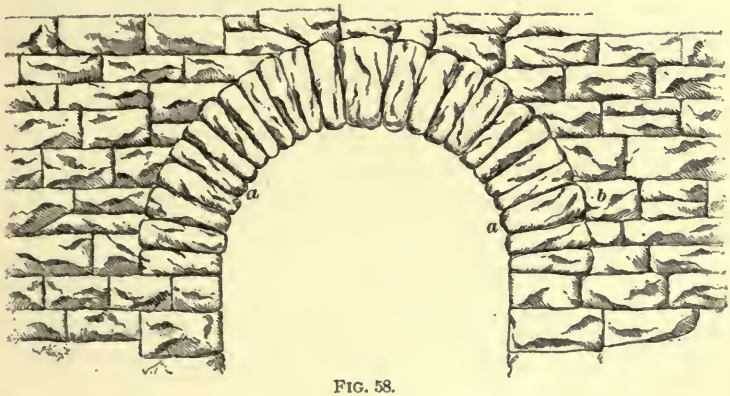


FIG. 58.

to a wedge shape. Such arches should always be laid in cement mortar, as they depend considerably upon the adhesive power of the mortar for their stability.

CONSTRUCTION OF ARCHES.

104. Voussoirs.—The ring of the arch should be built of the very best kind of ashlar masonry, cut, so that the voussoirs bear evenly and closely against one another, with the thinnest possible joints, as it is desirable to have but little mortar between the stones. The width of the ring stones is seldom less than 1 foot, or more than 2 feet, and the thickness (back into the wall) varies from 1 to 3 feet. The joints of the stonework should be the same width throughout the arch, so that the bearing may be uniform over the entire surface. The thickness of the joints depends somewhat upon the character of the finish. If the work is finely dressed, $\frac{3}{16}$ inch is the usual thickness; while in rock-faced work it is seldom made less than $\frac{3}{8}$ inch; $\frac{1}{4}$ inch is all that is usually allowed for the best work.

105. Usually the arch is divided into an odd number of voussoirs, and the keystone is placed in position last. Except for the convenience of the masons in laying, and for the sake of appearance, there seems to be no special reason for an uneven number of voussoirs, and some authorities claim that an even number makes a better job. Narrow voussoirs, while more economical in the amount of material used, are more expensive in labor, as more cutting and fitting is required than with wider ones.

Sometimes two of the voussoirs are cut from one stone, with a false joint between. Although this is generally done for economy, there are cases when the stability of the arch is thereby increased; as, for example, when the skewbacks are made twice the size of the remaining voussoirs, the number of joints is decreased, thus tending to strengthen the arch. In the case of a pointed arch, as shown in Fig. 52, the keystone should be made in two pieces, as the danger of its cracking or slipping is very much lessened when this is done.

106. Backing.—As a rule the cut-stone arches in buildings are only from 6 to 8 inches thick, having a backing of a less costly kind of stonework. Large arches, especially

when both sides are visible, as in some entrances, porches, etc., are often constructed as shown in Fig. 61. In this case, the stone ashlar is backed with brick, and tied together with clamps, as indicated at *f*.

107. Beams and Tie-Rods.—When an arch is to be built in a position where sufficient abutments to resist the arch thrust cannot be provided, one or more steel beams should be laid on the wall immediately over the arch, with the ends resting on the masonry forming the abutments. Anchor rods, securely embedded, should be used to tie together the beams and the stonework. Immediately below the middle of the beam, a small space, or joint, without mortar, should be left, so that if the beams deflect under the load they will not rest upon the arch. This method relieves the abutments of the arch thrust due to the load, which is, instead, transmitted vertically to the supports.

In building a segmental arch it is a good precaution, if conditions permit, to tie the arch together with steel rods, to take up the thrust until the mortar in the masonry has thoroughly set.

108. Bonding.—Whenever arches are carried on piers or columns, care must be taken in cutting the springing

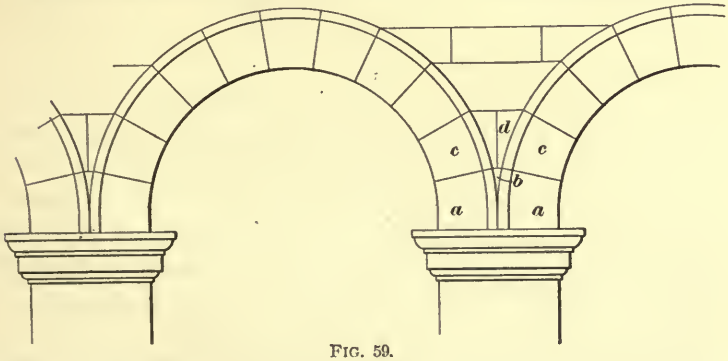


FIG. 59.

stones, so that they will bond properly into the spandrel masonry. In Fig. 59 are shown two arches springing from a pier; if the stones *a* are so cut that the wedge-shaped piece

b is necessary to fill up the space between them, there is danger that the weight of masonry over *b* will force it down, displacing the springing stones *a*; and similarly with the stones *c*. To prevent this, the stones *a* should be cut in one piece, while those marked *c* should be cut so as to make the joint come at *d*.

A somewhat similar case is represented in Fig. 60. Here the back of the arch extends almost to the corner of the wall, as shown at *b*. It is evident that, if the brick wall

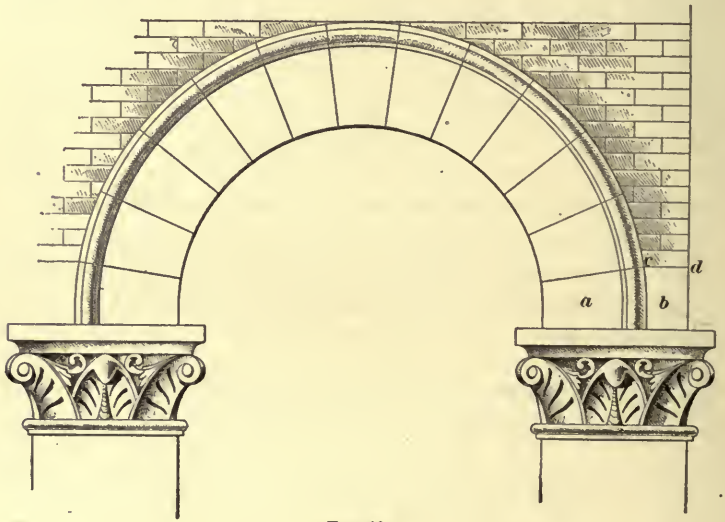


FIG. 60.

rests on such a small footing, it is liable to separate from the arch, thrusting out of place some of the lower bricks. In such a case, the lower voussoir *a* should be cut so as to extend to the corner of the wall, until the distance *c d* is at least 8 inches; more than this should be allowed if the wall is very heavy.

109. Molding.—Arches are often decorated with more or less elaborately dressed stone, known as *label* and *soffit* moldings. The former is sometimes cut in the ring stones, but oftener forms a separate course of thin stone. If such

is the case, the stability of the arch should not depend on the strength of the stone in the molding.

The soffit molding is frequently in the form of a bead and cone, or three-quarter round and cone, or some similar shape. Entrance arches are often decorated with various devices cut in the soffits, especially in entrances to cathedrals, public and office buildings, etc.

In Fig. 61, the label mold is shown at *a*; the arch rings,

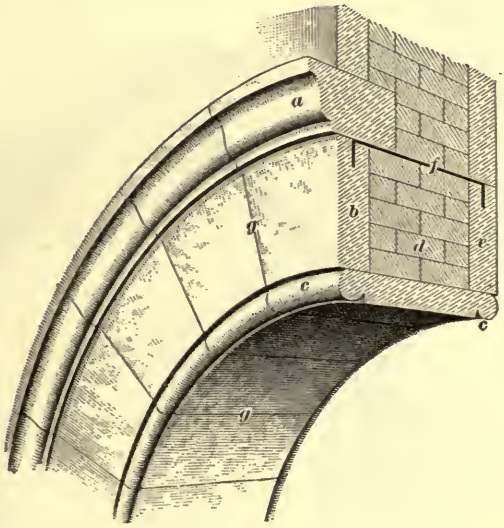


FIG. 61.

at *b* and *e*; the soffit mold, at *c*; the brick backing, or filling, at *d*; and the voussoir joints, at *g*. Every alternate pair of voussoirs should be tied together with galvanized-iron clamps doweled into the stones, as shown at *f*.

110. Centers.—In building an arch, it is carried up from both piers or abutments at the same time. During construction, the stones must be supported until the ring is completed. For this purpose, a framework, made of planks having one side cut to exactly fit the curve of the arch, is used. This framing, known as a *center*, is supported on posts; it is usual to insert wedges between the center framing and the posts supporting it, which, when the arch is

completed and the mortar has set, are driven out gradually, so as to bring the load on the arch ring without shock. The center should be strong enough to support the weight of the arch and a share of the wall above, as no weight should be put on the arch until the mortar in the joints has become hard.

111. Fig. 62 represents a form of center suitable for arches of small span. At *a* are shown the *bearers*, which

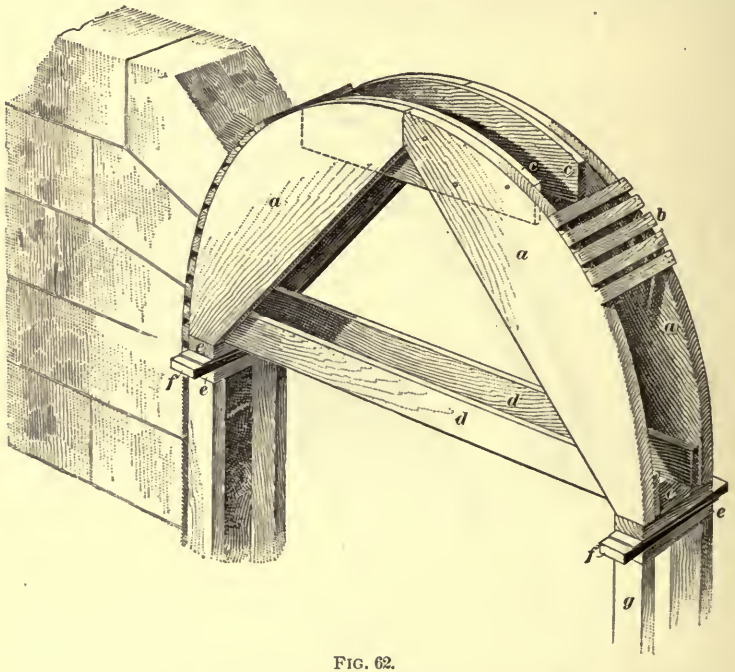


FIG. 62.

are cut out of 2-inch plank, to a radius about 1 inch less than that of the intrados of the arch. At *c* are indicated pieces of plank, nailed at the crown of the center to splice and stiffen it. Small bearing strips *b*, about 1 in. × 2 in. in section, are nailed to the curved pieces *a*. At *d* are the longitudinal braces; at *e* are the plates under the center and on top of the posts; at *f* are the wedges; and at *g*, the posts, which, if quite long, should be braced at the middle by struts.

112. For arches of considerable span, centers more strongly built are necessary. Fig. 63 shows a good form of construction. At *a* and *b* are represented the bearers, break-

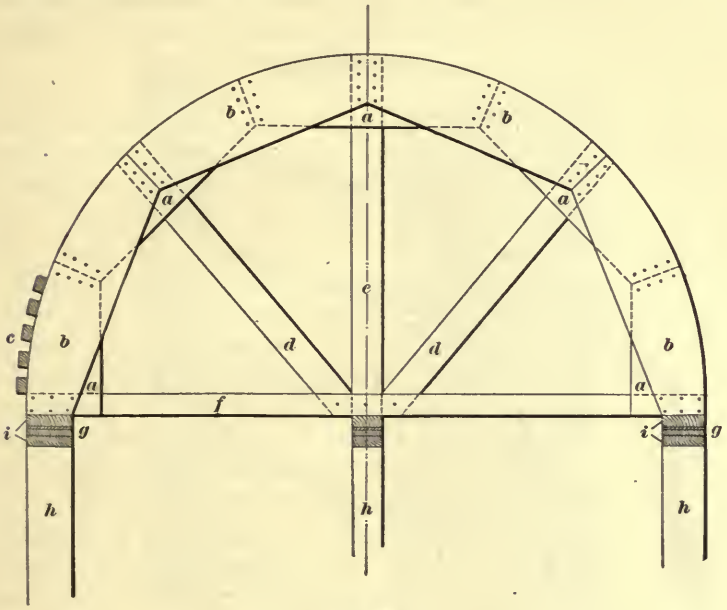


FIG. 63.

ing joint as shown; *c* indicates the bearing strips; *e*, the upright; *d*, the inclined braces; *f*, the tie piece; *i*, the bearing plates, with wedges *g* between; and *h*, the side and center posts.

POINTING STONEWORK.

113. The effects of the weather on the exposed edges of the joints in masonry usually cause the mortar to crumble and fall out. For this reason, it is customary to refill the joints, to a depth of from $\frac{1}{2}$ inch to 1 inch, with specially prepared mortar. This operation is called *pointing*. It is generally done when the walls are completed, but, if the season is too far advanced, it should be deferred until spring. Under no circumstances should it be done in freezing weather,

nor in extremely hot weather, as then the mortar will dry too rapidly.

Portland cement mortar, made of equal parts of sand and cement, and such coloring matter as may be desired, mixed with just enough water to give a mealy consistency, makes the most durable mortar for pointing.

114. Before applying the pointing mortar, the joint should be raked out to a depth of about 1 inch, cleaned with a stiff brush, and well moistened, so that the fresh mortar will adhere better to the stone. A pointing trowel is used for applying the mortar, which is thoroughly pressed in, and given a smooth surface by a tool called a *jointer;* at (*a*), Fig. 64, a concave-edged jointer is shown, and at (*b*), a convex-edged jointer. It will be seen that the jointer gives either a raised or a sunk joint, as may be desired. The latter is the more durable joint, but the first makes the best looking work.

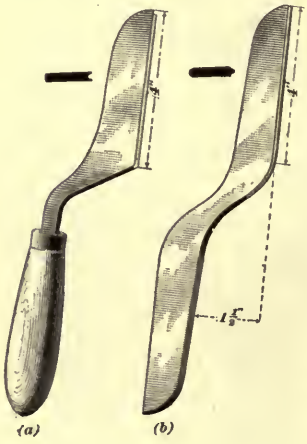


FIG. 64.

The different forms of pointing are shown in Fig. 65, in which *a* indicates the concave joint; *b*, the convex; and *c*, the convex projecting beyond the face of the stone.

CLEANING AND PROTECTING STONEWORK.

115. After pointing, it is usually necessary to remove the mortar stains, etc. from the face of the wall. This may be done by washing the stonework with a brush dipped in water containing muriatic acid, in the proportion of about 20 parts of water to 1 part of acid. For cleaning granite, marble, and limestone, wire brushes are used; for sandstones and other soft stones, stiff bristle brushes will serve the purpose.

The stonework should be scrubbed until all mortar stains are removed.

The sand blast, worked either by steam or compressed air, does the work of cleaning walls very effectively and

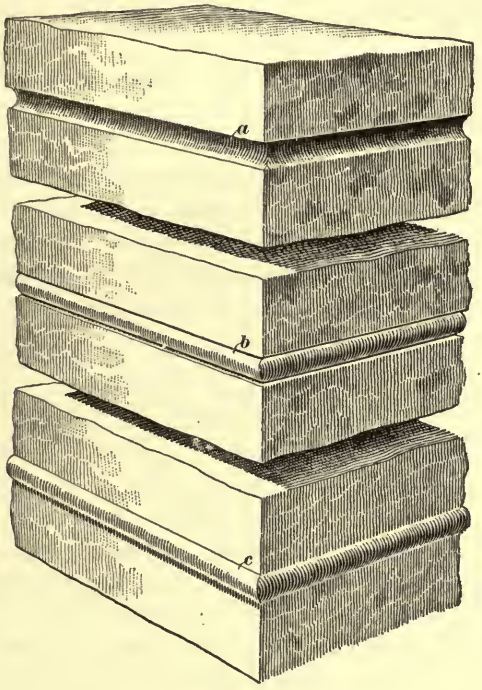


FIG. 65.

rapidly; it removes from $\frac{1}{64}$ to $\frac{1}{32}$ inch of the discolored stone, leaving a fresh, bright surface. Even fine carvings have been very successfully cleaned by this method.

116. The durability of masonry may be somewhat increased by covering the exposed surfaces with a preservative, but none of the numerous preparations for protecting stonework are cheap or satisfactory.

Lead-and-oil-paint is the most generally used for this purpose, but, while it may be temporarily effective, it spoils the

appearance of the stonework and requires frequent renewals, owing to the action of rain and other atmospheric influences.

Boiled *linseed oil* is also sometimes used, but darkens the color of the stone. To apply the oil, the surface of the stone is first washed clean and dried; the wall is then covered with one or more coats of oil, and finally washed with weak ammonia, which makes the coloring more even. Oil thus applied will last 4 or 5 years.

Another preparation is *paraffin* containing creosote, dissolved in turpentine. The purpose of the creosote is to prevent vegetable growths on the stone. Before applying the preparation, the stone should be heated in some manner; the melted compound is then applied with a brush. It will penetrate some kinds of stone to a depth of $\frac{1}{2}$ inch.

117. *Sylvester's process* consists in the application of two washes, the first composed of a hot solution of Castile soap in water, and the second of alum water, which is applied about 24 hours after the soap solution. This process has been found more or less successful, when the stone is not subjected to great variations in temperature.

A method, known as *Ransome's process*, has been used in England with good results. It consists in the application of a solution of silicate of soda or potash to the clean surface of the stone, until it has been thoroughly saturated. When this has dried, a solution of chloride of calcium is applied, the effect of which is to produce an insoluble silicate of lime, thus forming a waterproof coating. (See also Arts. **277** and **278**, *Masonry*, § 7.)

STRENGTH OF MASONRY.

118. The figures given in Table 2 are the safe bearing strengths of different classes of masonry. The first values may be used when the stonework is of fair quality and good lime mortar is used; the second ones, for the best quality of work with cement mortar.

TABLE 2.

SAFE BEARING LOADS OF MASONRY.

Kind of Masonry.	Bearing Value per Sq. Ft.
Concrete	5 to 15 tons.
Rubble	5 to 15 tons.
Squared Stone, $\frac{1}{2}$-inch joints	15 to 20 tons.
Sandstone ashlar, $\frac{1}{4}$-inch joints	10 to 20 tons.
Limestone ashlar, $\frac{1}{4}$-inch joints	20 to 25 tons.
Granite ashlar, $\frac{1}{4}$-inch joints	25 to 30 tons.

119. A column of good stone, which is carefully set and has well dressed bearing surfaces, should, if its height is not over 10 times its diameter, safely carry a load about one-fifteenth of the breaking load of stone of the same quality. Table 3 gives the safe bearing values for different kinds of stone columns, when the shaft consists of a single piece:

TABLE 3.

SAFE LOADS ON STONE COLUMNS.

Kind of Stone.	Load per Sq. Ft.
Sandstones—	
Potsdam, N. Y., best	40 tons.
Longmeadow, Mass., best	35 tons.
Manitou, Col., best	25 to 30 tons.
Ohio	25 tons.
Fond du Lac, Wis.	25 tons.
Limestones—	
Glens Falls, N. Y.	35 tons.
Indiana	25 to 35 tons.
Marble—	
Good quality	40 tons.

120. A column should not carry a greater weight than 40 tons to the square foot, as, while the stone itself might carry much more, the mortar joint is the weakest part, and hence is most likely to fail. When a column is loaded with over 15 tons to the square foot, it should be set in Portland cement mortar, made of equal parts of cement and sand, which should not be laid within an inch of the face until the building is finished and the mortar has thoroughly set, when the joints may be pointed. If a column consists of several pieces, the joints should not exceed $\frac{3}{16}$ inch in thickness, and the bed surfaces should be very finely dressed, perfectly true, and perpendicular to the axis of the column.

MEASUREMENT OF STONEWORK.

121. At the quarry, stone is divided into two classes: *dimension stone* and *rubble*. The first consists of those pieces which are quarried in regular shapes, and to a fixed size, usually 24 inches square or more in area, and over 8 inches thick. This class of stone is generally sold by the cubic foot, and costs about three or four times as much as rubble.

Rubble includes pieces of various sizes and shapes which form the waste in quarrying the larger stones. It is suitable for work in which the courses are 12 inches or less in height, and the stones are not over 24 inches long. Generally speaking, all stone not quarried to a certain size may be termed rubble. It is usually sold by the carload, or in small quantities by the perch, and in some places by the ton.

122. The methods of measuring stone are very unsatisfactory, owing to the great difference in practice in various parts of the country. *Dimension stone* footings are generally measured by the square foot. If built of large rubble, or irregular stones, the footings are usually figured in with the walls, with allowance for the extra width. *Rubble* is usually measured by the perch, which, unfortunately, varies from 16 to 25 cubic feet, being $24\frac{3}{4}$ cubic feet in the Eastern

states, $16\frac{2}{3}$ feet by custom in Colorado, and 22 to 25 cubic feet in various other places. A necessary precaution, to prevent disputes, when work is to be measured by the perch, is to agree on the number of cubic feet in a perch, and also in regard to deductions for openings. If this is not done, the custom of the particular locality would probably govern in case of disagreement. In some places, rubble work is measured by the cubic yard of 27 cubic feet, or by the cord of 128 cubic feet. Stone backing is commonly figured the same as rubble.

Ashlar masonry is almost invariably measured by the square foot, the cost depending on the kind of work and size of the stones. It is usual to deduct openings in ashlar work; when the width of the jambs of windows is more than the depth of the ashlar, the jambs are usually measured in with the face work. *Flagging* and all thin pieces or slabs are figured by the square foot.

Moldings, *belt courses*, and *cornices* are usually measured by the lineal foot, but if the shapes are not regular they are figured by the cubic foot. All carved work is estimated by the piece.

Trimmings are sometimes figured by the cubic foot, the price varying with the amount of labor required in dressing. Probably the most accurate way of figuring this class of work is to first estimate the value of the rough stone, and then that of the labor involved in the different classes of work, the resulting prices being per lineal foot. This method is the one usually employed in figuring granite work.

INSPECTION.

123. The inspector or superintendent should be very careful to have the work properly done, during erection, both in cutting and setting stone, as an imperfect piece, when once set in place, can only be taken out with considerable trouble. The stones must also be carefully examined, as otherwise, many cracked and defective ones may be used, either by accident or design. The qualities of the stone

should, in a general way, be similar to those enumerated under "Qualities of Building Stones."

Granite may contain cracks, black or white lumps known as *knots*, and a brownish stain called *sap*. If such defects are found, the stone should be rejected, if the importance of the work justifies it. The first mentioned is the most to be guarded against, however. Cracks may be discovered by the absence of the clear ringing sound when the stone is struck with a hammer. *Sand holes* are frequently found in sandstones. These are bodies of uncemented sand which become dislodged by jarring or by the action of water, producing a pitted appearance and an uneven color. Attention must also be paid to securing uniformity of color, as sandstone from different parts of the same quarry may vary greatly in this respect.

124. *Patching* is an operation often resorted to by contractors, when a small piece has been broken from a large stone. Instead of using a new stone, the old one is patched by gluing on the spall with shellac, the joint being hidden by rubbing stone dust over it. Rain, however, will render the joint useless by washing out the shellac, so that the patch falls off. There are times when a patch is allowable, as, for example, when a new stone cannot be had without great expense and delay. In such a case, the superintendent may permit it, but care should be taken to put on the spall by inserting it, when possible, in a square hole, or dovetailing it in such a way that it will not become displaced.

125. The most common faults of cut stone are poor workmanship and coarseness of surface. Most builders will naturally avoid any extra work in dressing beyond that necessary to be barely acceptable to the inspector.

Frequently the ends of cornices, belt courses, etc. will not properly match. It should be strictly required that the utmost care be exercised in cutting all similar pieces to the same pattern, and that the abutting surfaces be closely dressed.

Stone window sills are often not wide enough to be covered by the wood sill. This should be guarded against;

otherwise, the access of rain will cause dampness in the walls and disintegration of the mortar. The wood sill should overlap the stone one at least 2 inches, fitting closely upon it.

126. Care should be used to have the stone set on the natural bed, with good joints, and not in too small or thin pieces. The bed joints, in ashlar work, should be square to the face of the work, and not less than 4 inches wide at both top and bottom. The proper bonding of the walls, especially the ashlar and trimmings, should be given very careful attention, as well as the placing of lintels, copings, wall anchors, etc.

Another point needing attention is to have the mortar, in joints on which great pressure comes, kept back from the surfaces; otherwise, the edges may chip off. Also, before pointing is done, have the joints well raked out and the pointing mortar laid properly.

Many other precautions for the good performance of the work will doubtless suggest themselves to the careful superintendent.

CONCRETE CONSTRUCTION.

USE AND VALUE.

127. The value of **concrete,** as a substitute for stone and brick, has been known for many centuries, and is to be seen in the ruins of ancient Roman temples and palaces, in domes and arches, in the core or interior of brick-faced walls, and in their foundations.

Although, for many years past, engineering works of great extent have been constructed of concrete, it is only within a quite recent period that this valuable material has come into considerable use in this country for building purposes, except as footings for foundation walls, for which it has long been used. Although it is not probable that concrete will ever entirely take the place of stone and brick, yet, both alone and in combination with iron and steel, it is of great value for various constructive purposes. Suitable materials for

the manufacture of concrete can be found in almost every locality, which, with its comparative cheapness, makes it an important substitute for brick and stone in ordinary structures. In many places, cottages, and even large edifices, have been built of concrete. Instances of the magnitude of such construction are several very large hotels at St. Augustine, Fla. In one of these, the basement is a bathing pool 100 feet long, 60 feet wide, and from 3 to 10 feet deep, constructed entirely of concrete. This basin is surrounded by columns 6 feet square at the bottom, and 40 feet high, carrying concrete arched beams of 25 feet span, supporting the roof over the interior court.

METHODS OF CONSTRUCTION.

MOLDS.

128. It is usual to build concrete walls, piers, arches, etc. by depositing the concrete in forms, or **molds,** made somewhat as follows: Posts of $4'' \times 4''$, or $4'' \times 6''$ timber are set up in pairs on opposite sides of the wall where the blocks are to be formed, each pair being strongly bolted, to prevent springing. Against the inner sides of the uprights are laid planks, $1\frac{1}{2}$ or 2 inches thick, the distance from face to face of the boards being just the thickness of the wall. The planks frequently have beveled ridges formed on the inner side, to produce the appearance of joints in the wall. This is shown in Fig. 66, in which *a* represents the posts; *b*, the boarding; and *c*, the molded or beveled strips, which make the apparent

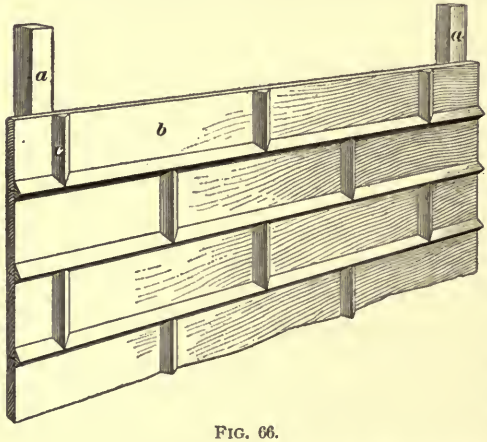


FIG. 66.

joints when ashlar is to be imitated. It is evident that any kind of stone masonry may be simulated, by varying the position and shape of the strips or cleats.

It is recommended that the inside of the molds be washed with a solution of soap before laying concrete between them.

After the lower portion of the concrete wall has set, the bolts in the uprights are loosened enough to permit the withdrawal of the molding boards, which are put in place higher up. A movable cribbing is often used, consisting of slotted standards, which are raised, when necessary, without interfering with the work of laying the concrete.

MAKING AND LAYING CONCRETE.

129. The **concrete** should be made of a good quality of Portland or best Rosendale cement, mixed with clean, sharp sand, and a proper amount of aggregates. The proportions vary for different classes of work, but a common ratio is 1 part of cement, 2 parts of sand, and 3 or 4 of crushed stone, or similar material. Any natural stone, gravel, broken brick, etc. may be used, but, whatever it is, it should be uniform in color and of an even grade. If a very close imitation of a natural stone is desired, the same stone should be crushed, and in addition, color should be mixed with the cement, to correspond with that of the stone. The finer the stone is crushed, the nearer will be the resemblance to real stone. For very good work, it is sufficient to break the stone to the size of buckshot or fine gravel.

In the construction of the large Florida hotels, before referred to, the concrete was composed of 1 part Portland cement, 2 parts sand, and 3 parts of *coquina*, a small shell found in large quantities in the vicinity. These shells are so small that most of them will pass through a $\frac{1}{2}$-inch mesh sieve. The color of this concrete is a light gray, hardly darker than Indiana sandstone or Westerly, R. I., granite. When a different effect was required, coloring matter was introduced into the cement. The cost of the concrete in place varied from $5 to $8 per cubic yard, including arches, columns, etc.

130. Machine Mixing.—Concrete mixing by hand has been described in *Masonry*, § 7. When, however, large quantities are needed, it is usually mixed by machine. The most common one consists of a long screw, about 18 inches in diameter, enclosed in a slightly inclined iron casing of a little greater diameter; the screw is operated by a crank, turned either by hand or by power. The cement, sand, and stone are introduced through hoppers at the upper end, and the water is added through pipes at intervals along the length, and as the screw revolves, the materials become thoroughly incorporated. The concrete is forced out at the lower end of the machine, falling into the bucket or other conveyor. After the concrete is made, the time between the mixing and the ramming in place should be as short as possible, in order to prevent the cement from becoming set.

To hoist the prepared material, a traveling crane is sometimes used, the concrete being placed in buckets, which are transported to the proper place by the crane. Another plan is to have an elevator built at a central point on the site and carried up to the full height of the intended building, runways being made to each floor, as the work progresses.

131. Laying Concrete.—When the concrete has been dumped out of the conveyor at the proper place, it is spread out on top of the previous layer, the top of which should be somewhat rough and uneven, so as to make a better bond with the new work. The fresh concrete is then settled, by ramming or otherwise, and the operation is continued until the concrete is thoroughly consolidated, and the cement flushes to the surface, which, as before, should be left rough for the succeeding layer. Too much care cannot be exercised in these operations, as on the compactness and uniformity greatly depends the value of concrete construction.

The making and placing of concrete should be very closely inspected, to insure the specified quality and proportions of cement and other materials, and proper manipulation. The cement used should be frequently tested during the progress of the work. Some simple tests are given in the articles on

"Cements," in *Masonry*, § 7. On large and important work, an inspector should be kept constantly on the ground, to see that the concrete is properly mixed and laid.

132. Expansion and Contraction.—When concrete sets in air it contracts slightly, but often sufficiently to produce cracks in the walls and floors. To prevent this, it is customary to employ some means to allow for expansion and contraction. The usual method is to make false joints in the work, which the cracks will follow, and will not appear on the face of the wall.

A method of accomplishing this object is represented in Fig. 67. A $\frac{1}{8}$-inch iron plate, usually the height of a course

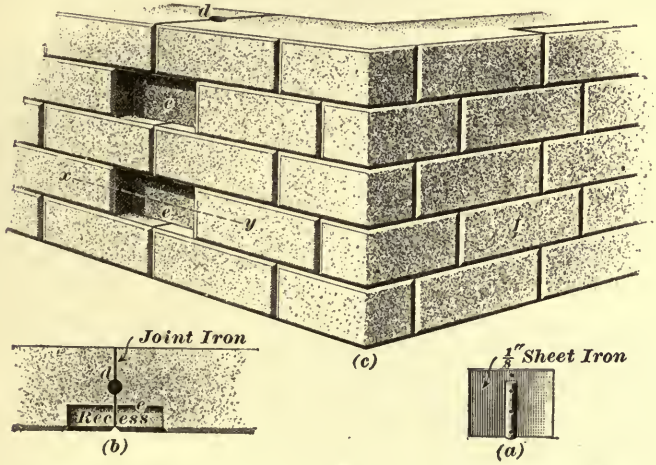


FIG. 67.

of concrete, is shown in plan at *d*, in (*b*), which is a cross-section on line *x y* in (*c*); a front view of the jointer is shown in (*a*). The plate is set upright, in line with one of the vertical strips which form the false joints, and the concrete is laid on both sides of it; when the latter has set, the plate is pulled up, leaving an open joint through the wall, as seen at *d* in (*c*). Wherever these are made, spaces are left in the face of the blocks above and below, as shown at *e* in (*b*) and (*c*). Such joints permit the concrete to contract and settle without defacing the wall. When these

actions have ceased, the recesses are filled with closely fitting blocks, laid in strong mortar. At *f* is shown a block, or plate, inserted, which, when properly put in, is undistinguishable from the rest of the work. This plan has been found very effective in preventing the appearance of disfiguring cracks on the exterior of the walls.

In placing band courses, trimmings, etc., much care must be taken to have them so arranged that shrinkage in the concrete will not injure them. All window sills should be slip sills, so that, if the wall settles, the ends of the sills will remain unbroken. For similar reasons, it is well to have the window lintels made in the form of a flat arch with a through joint at the center, and a recess for a key, which is put in later.

133. Surface Finish.—Up to within a few years, the outside covering of most of the concrete buildings was plaster or mortar; this finish, however, does not prove satisfactory, and increases the cost considerably. It is now customary to cut the outside faces of concrete walls to closely resemble rough-dressed stonework. Since concrete is artificial stone, some form of finish is as necessary for it as for natural stonework. The effect of coursed stone or ashlar is produced by forming imitation joints in the face of the wall, as shown in Fig. 68, and afterwards either picking or tooling the surface. In imitating rough-dressed work, the crib, or mold, is taken from the concrete wall before it becomes absolutely hard, and the finishing may then be done very rapidly. When an imitation of finer tooled work is desired, the concrete should be allowed to harden for a longer period before being cut.

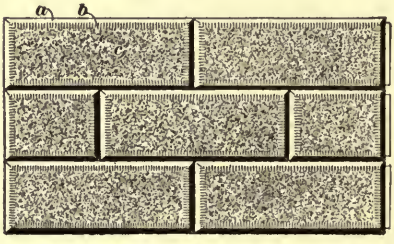


FIG. 68.

Fig. 68 represents a method of finishing the face of concrete blocks; *a* shows the joint in the concrete; *b*, a

margin, or draft, cut to imitate tooled work; and *c*, the picked face. If the strips which form the apparent joints have been properly planed and beveled, the recessed joints should need no dressing.

HOLLOW CONCRETE WALLS.

134. Sometimes the walls of concrete buildings are made hollow and strengthened by twisted steel rods, which form what is called the *Ransome system* of concrete construction. Fig. 69 represents a section of the wall in a

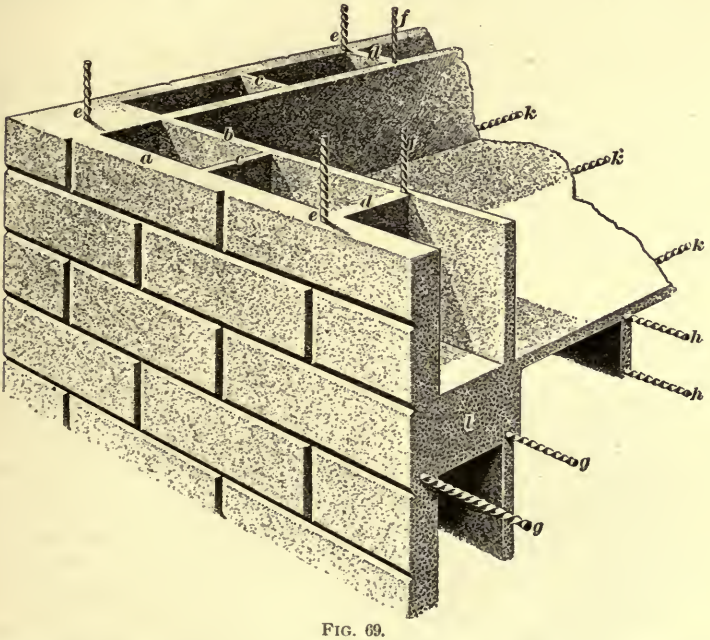


FIG. 69.

structure so built. At *a* is shown a 6-inch outer concrete wall; at *b* is a 2-inch inner wall; and at *c* and *d* are vertical *withes*, tying together the two portions. (See "Hollow Walls," in *Masonry*, § 7.) Those shown at *c* are $1\frac{1}{2}$ inches thick, while at *d* they are 3 inches, in order that the twisted rods may be better embedded. The 1-inch rods on the outside wall are shown at *e*, and the $\frac{3}{4}$-inch rods in the inner wall at *f*; these rods are placed from 12 to 15 feet apart.

At *g*, *h*, and *k* are the tie-rods in the floor construction. In the withes marked *d* and *e* are placed $\frac{1}{4}$-inch rods, set horizontally and spaced about 12 inches apart vertically; and at each floor level, $\frac{3}{4}$-inch bars are embedded in the walls, as shown at *g*. At all meeting, or crossing, points the rods are securely attached or tied to one another. The spaces in the walls are stopped at each floor, as shown at *l*, excepting those for ventilation or those used as smoke flues, which are continuous. The interior partitions are also concrete, with twisted rods, and, being monolithic, they further increase the stiffness of the structure.

This form of construction has the advantage of great strength, as the twisted rods tie the walls together in all directions, while the shape of the wall gives stability without waste of material. It is also superior to hollow-brick walls, as practically no moisture will pass through the concrete withes. The average cost per square foot of exterior surface, in a large building so constructed, is about 25 cents.

OTHER USES OF CONCRETE.

135. Concrete Beams and Lintels.—When these are to be made, they should be formed of concrete and twisted iron or steel rods. Fig. 70 indicates the method of construction; *a* shows the concrete beam carrying the wall *e*; *b*, the lower range of twisted bars, 1 inch in diameter; *d*, other bars placed near the top of each lintel, where it comes over a pier or column, thus practically making a continuous girder; and *c*, one of the supports of the beam.

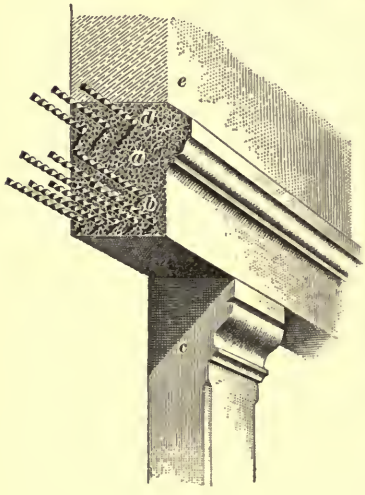


FIG. 70.

136. Fireproof Vaults. Another of the numerous uses to which concrete is put is in

the construction of fireproof vaults, for which it forms a very valuable material, remaining intact even if the building is wholly destroyed. The concrete is laid, as before described, in a monolithic mass. Rails, etc. are frequently embedded in the concrete to stiffen it, as well as to make it difficult to cut through by burglars. The vault is further rendered proof against thieves by laying copper wires at short spaces throughout the concrete, forming a continuous circuit, and suitably connected with an alarm.

TERRA COTTA.

VALUE IN CONSTRUCTION.

137. The uses of terra cotta in architectural work are so varied and extensive as to be almost endless. Both for inside and outside decorative and plain work, it forms a very important substitute for stone and brick, especially in positions exposed to the weather.

Although terra cotta has come into extensive use within a comparatively recent period, it has met all requirements very satisfactorily, showing itself to be of the utmost value as a durable building material. In Europe are to be seen many examples of terra cotta which have endured the changes of the weather for hundreds of years and yet remain in good condition, while stone similarly exposed has become more or less disintegrated.

The great value of terra cotta for building purposes consists in its durability. If made of the right kind of materials, and properly burned, it is practically impervious to moisture, and hence is not injured by frost, which is such a powerful destructive agent in many building stones. Atmospheric gases, likewise, have no effect on well burned terra cotta, and dirt gathering on it is washed away by rain. Another point of value is that it affords no lodgment for vegetable growths, as do some stones. When terra cotta is not sufficiently burned, it lacks the proper surface vitrification,

and is then to some extent absorbent, and, consequently, not so durable. The heat-resisting power of terra cotta also gives it a great advantage over other materials, and makes it very desirable to use for trimmings and ornamental work in fireproof buildings.

138. Economical Advantages.—The cost of terra cotta varies according to the size and amount of work required. Plain sills and caps can be obtained at about the same price as those of dressed sandstone, when the price of the rough stone does not exceed 90 cents per cubic foot. When many pieces of the same size and shape are required, terra cotta can be had much cheaper than stone, unless the charges for transportation are very high. When there are many molded and decorative features which would necessitate much hand work for dressing and carving, if stone were used, the advantage in terra cotta in point of cost is evident. Further economy may be obtained by repeating the detail of the ornamental features, so as to require the fewest possible different pieces. Very often suitable designs may be found in catalogues of terra-cotta manufacturers, by using which the cost will be considerably less than when new patterns and molds must be made for the work. Another advantage is that terra cotta weighs less than stone, and, consequently, lighter walls may be made, when the former is extensively used, than if the work were wholly of stone.

MANUFACTURE OF TERRA COTTA.

139. The material in terra cotta is practically the same as that in brick, but a much better quality of clay must be used, and the method of manufacture is also different from that of brick. The proper selection of the materials used requires considerable skill and knowledge of effects to secure desired results. The clays used are obtained from different places, and must be mixed in certain proportions in order to obtain certain results. Much artistic skill is necessary to produce the elaborately decorated work now so common,

and consequently terra-cotta manufacture ranks much higher than brickmaking.

140. After the clay is mined, it must be seasoned by exposure to the air for some time. It is then ground and mixed with water and materials known as "grog," which, in burning, produce a partial vitrification, thereby increasing the durability of the terra cotta. Grog usually consists of very fine white sand, pulverized firebrick, partly burned clay, and fragments of pottery. The mixed clay is then piled in layers, each quality being kept separate. Ten or twelve strata are laid, and the mass is cut up into sections and again thoroughly mixed by being run between rollers, or through a pug mill, the object being to secure a complete and uniform mixture of the ingredients. The plastic clay is then formed into cakes of convenient size for handling, and is ready for the molder.

If only a single piece is to be used, the clay is modeled directly into the required shape, no molds being used. When, however, numerous pieces of the same size and shape are to be molded, a full-sized model of plaster and clay is made, from which a cast of plaster is taken; this is thoroughly dried before use. The tempered clay is compacted into the mold and allowed to become partially dry; it is then taken out and sent to the carver or modeler, if it requires decoration, or to the clay finisher, if it merely needs "touching up," or trimming. The unburned terra cotta is next removed to the drying floor, which is kept at a temperature of between 70° and 80° F., and is dried thoroughly, and is then ready for the kiln, in which it remains about 7 days for burning and cooling. In the burning an efflorescence is formed, which, on cooling, becomes hard and vitrified, rendering the material more durable; this glaze should not be broken unless it is necessary to do so.

141. Terra cotta is usually made in blocks from 18 inches to 2 feet long, and from 6 to 12 inches deep, the height depending upon the position and character of the

work. To economize material and prevent the blocks becoming distorted and out of line, they usually consist of an outer shell, braced by partitions about 1 inch thick; these should not be more than 6 inches apart, and should be perforated, so that the mortar may form a good bond between the piece and the brick filling.

Owing to the improvements in methods of manufacture, terra cotta may now be had in almost any shade, from nearly pure white to a deep red; but previous to about 15 years ago, most of the terra cotta produced had a red color. The shades most commonly used at present are tints of gray, white, bronze, red, etc. Any color may be produced by chemical means, but a better quality of material is likely to result if those colors are used which are natural to the clay, and which do not require overburning or underburning of the clay to produce the desired effect.

CONSTRUCTION DETAILS.

142. Size of Pieces.—In designing any terra-cotta work, care should be used in limiting the size of the pieces to the most practical and economical dimensions; these may be said to be under 3 ft. $\times$ 4 ft. $\times$ 18 in. Columns have been made 14½ feet in length, the shaft being in one piece 12 feet long, but such sizes are very costly, as great skill and care is necessary in their manufacture to prevent warping.

Window openings of more than ordinary width, should not be spanned by single pieces of terra cotta. Sills are usually formed of blocks, not over 2 feet long; the height of the pieces composing the jambs should not be more than 12 inches. In fact, all the work should be divided into as many pieces as possible, care being taken to insure proper bonding. Short lengths are more easily handled, and less liable to break than long ones. When brick structures are trimmed with terra cotta, it is essential that the pieces be of the same height as the courses in the brickwork, in order that they may bond well into it.

143. As considerable time and extra expense are required for manufacturing special shapes of terra cotta, use should be made of such standard forms and sizes as are readily obtainable, when these can be used; but when the pieces must be made to order, the drawings should be sent to the manufacturer at least two months before the terra cotta is needed, to allow ample time for manufacture and delivery. While small pieces may often be obtained in less time, it is not advisable to force the work, as it increases the cost greatly, besides preventing thorough drying of the blocks.

144. Weight and Strength.—Solid blocks of terra cotta will weigh about 120 pounds to the cubic foot. Hollow pieces, with walls $1\frac{1}{2}$ inches thick, will weigh from 65 to 85 pounds per cubic foot, small pieces being heavier per cubic foot than large ones. An average weight is 70 pounds per cubic foot for blocks 12 in. $\times$ 18 in. or larger on the face.

Two-inch cubes of terra cotta crush under a weight varying from 5,000 to 7,000 pounds to the square inch. Authorities give the safe working strength of terra-cotta blocks in the wall at 5 tons per square foot, when unfilled, and 10 tons per square foot when filled solid with concrete.

145. Setting and Pointing.—Before use, each piece of terra cotta should be carefully inspected. It is important that abutting surfaces shall match perfectly and that each piece shall fit exactly in its proper place. Terra cotta should give out a clear metallic sound when tapped with a hammer; and a fracture should show a close and homogeneous texture and uniform color. The surface should be hard enough to resist a knife scratch. Broken or twisted pieces, or any having the glazing chipped off, should not be used.

The mortar used in setting terra cotta should be composed of good cement and sand, mixed in about the proportion of 1 to 2. The method of laying the blocks is similar to that of stone setting, and is generally done by the bricklayer, the terra-cotta work being carried up simultaneously with the brickwork. The blocks should be solidly built into or

anchored firmly to the walls, and all voids should be filled with brick and mortar, to make as strong work as possible. Immediately after the pieces are set, the face joints should be cleaned out at least $\frac{3}{4}$ inch in depth, so as to prevent spalling the edges of the blocks, and to make ready for pointing. The mortar in all horizontal joints exposed to the weather, should be raked out to a depth of 2 inches, and the joint should be calked with oakum, about 1 inch deep, the remaining space being pointed in the usual manner. The pointing mortar should be made of about 1 part each of cement and sand, and colored to correspond with the terra cotta.

146. Fig. 71 represents a good example of terra-cotta work, showing the accuracy and neatness with which the

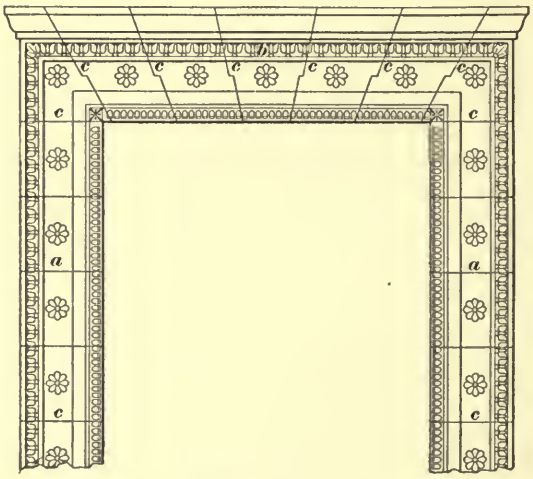


FIG. 71.

pieces may be manufactured and laid. The figure represents a doorway, *a* being the jambs, and *b* the lintel, which is formed of several pieces, joined at *c*.

147. When window sills are made in sections, they should have lap joints, as represented in Fig. 72, in which *a* shows the pieces of terra cotta; *b*, the joint, protected by the

half-round roll *e*; *c*, the wood sill of the window; and *d*, the

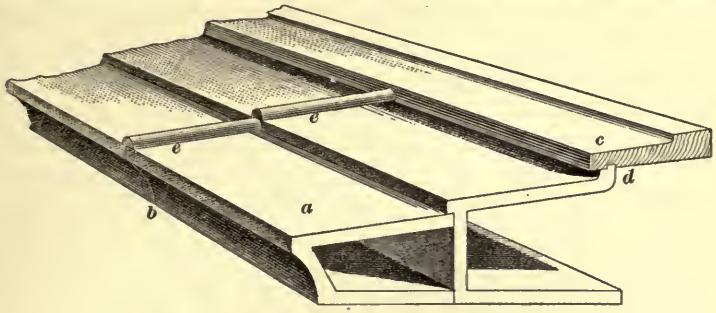


FIG. 72.

joint between the terra cotta and the wood. This is a very good method of construction, as the insertion of the terra cotta under the wooden sill prevents water penetrating the wall during driving rains.

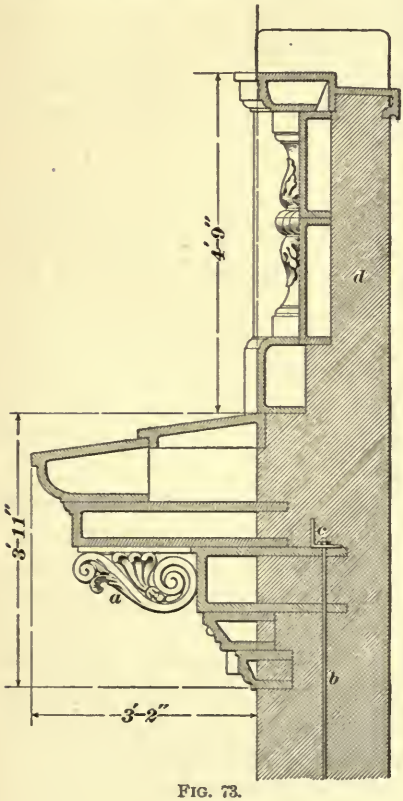


FIG. 73.

148. Cornices.— For these, terra cotta is greatly used, as it is much lighter, and usually cheaper, than stone, especially if the work requires elaborate decoration. When a stone cornice is built, it is always necessary, in order to balance it, that the projection of the pieces composing the cornice shall be less than the portion extending into the wall. A terra-cotta cornice, however, does not require this, as the various pieces may be made to enter the wall only from 8 to 12 inches, being held in

place by ironwork embedded in the masonry. Small angles, I, or T beams are generally used to support the projecting pieces of a cornice. If the projection is considerable, the inner end of the beams should be anchored by rods carried down into the wall until there is enough masonry above the anchor to insure stability. When the wall carrying the cornice is light, it is well to anchor the top of the wall to the roof timbers, so as to prevent its inclining outwards. If iron is to be used for tying the cornice to the wall, it is necessary to determine the method of anchoring before the pieces are molded, as, in manufacturing them, holes or slots must be made for inserting the beams, rods, and anchors.

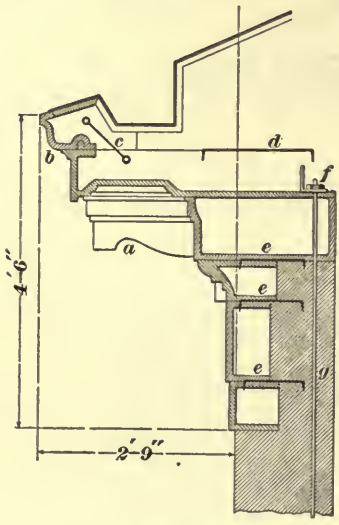


FIG. 74.

149. The method of placing and anchoring terra-cotta cornices is shown in Figs. 73, 74, and 75. In Fig. 73 is represented a cornice having a projection of over 3 feet. At *a* is shown the bracket extending into the wall, and held in place by an iron rod *b* bolted to the angle *c*, which runs longitudinally through the wall; the rod *b* has an anchor plate at its lower end.

In Fig. 74 is shown another cornice, having considerable projection; *a* shows the bracket; *b*, the crown mold; *c*, a tie or clamp holding the upper portions of the cornice together; *d* and *e*, anchor rods tying the various portions of the cornice to the wall; *f* and *g* are respectively the angle and anchor rod.

In Fig. 75 is shown a more elaborate cornice, having a projection of 4 feet. It is essentially similar to those just described, the principal difference being in the use of angles extending into each bracket, supporting it as shown.

150. Terra cotta is also very extensively used for

roofing purposes, but as that subject is dealt with in *Roofing*, it is unnecessary to consider it in this place.

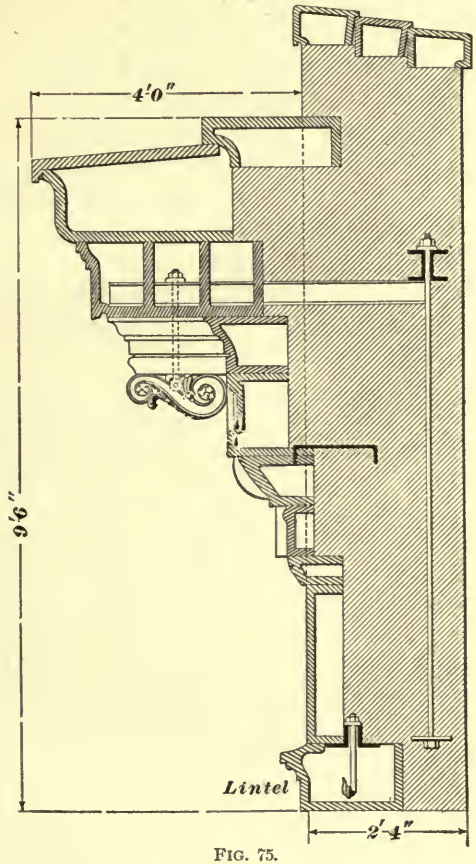


FIG. 75.

FIREPROOFING.

INTRODUCTORY.

151. As the materials made use of in modern fireproof construction, to protect the structural parts of buildings from fire and heat, come within the province of the architect, a good knowledge of the systems and methods in use is necessary for the intelligent design and direction of the work.

Probably the nearest approach to an absolutely fireproof structure is a building constructed entirely of brick and terra cotta, with tile or brick arched floors, and vaulted roof, so that no iron or wood is needed for structural purposes. Such a building, if large, would naturally need thick walls and massive piers, occupying considerable space. The value of land in large cities requires the utmost economy of space, and for this reason the columns in a business structure must be as few and as far apart as consistent with safety, and the distance between the ceilings and the floor above must be as little as possible. Such conditions necessitate the use of some stronger and less bulky materials, such as iron and steel, protected in some manner from direct exposure to fire or heat.

Buildings having wooden posts, beams, etc., are rendered fireproof almost entirely by plaster laid on metal lathing, or with plaster boards or blocks; these methods will be described under "Plastering."

152. Before the plans for the building are made, the material and method of construction to be used should be decided on, as some of the fireproof systems require particular arrangement and shape of the supporting members.

The principal fireproof materials are brick, terra-cotta tiles, and concrete, the latter being bound together and strengthened by steel bars, wire, or netting. Nearly all methods of fireproofing are covered by patents owned by large manufacturing concerns, which, usually, will undertake to supply and set all the fireproof material used in a building. This plan is productive of much better results than when the work is done by inexperienced contractors.

FIREPROOF MATERIALS.

153. **Tiling** consists of clay molded in either solid or hollow shapes, and thoroughly burned. It may be divided into two general classes. The first is variously termed porous terra cotta, cellular pottery, porous tiling, soft tiling, etc.; the second is called fireclay tile, hollow pottery, hard tile,

terra cotta, dense tiling, etc. In this section, the first kind will be hereafter referred to as *porous* tiling, and the second as *dense* tiling.

154. **Porous** tiling has the advantage over hard tiling in that it is elastic, tough, and light. It is composed of sawdust, finely cut straw, and tough plastic clay, to which a small proportion of fireclay has been added. The mixture is exposed to an intense heat, which burns out the sawdust and cut straw, leaving a light, porous material resembling pumice stone. When properly made and burned, it will endure unequal heating or sudden cooling without cracking. It may be cut with a saw or chisel, and nails or screws may be easily driven into it. Properly made porous tile has a compact, hard, and tough texture, and gives out a ringing sound when tapped with a hammer. Tile made from sandy clay, or from material poorly mixed and burned, shows an uneven, soft, and crumbly fracture, and should be tested before using. Whenever porous tile has considerable weight to carry, as in floor construction, the shell should be at least 1 inch in thickness, and the webs, or partitions, between the cells should be about $\frac{3}{4}$ inch thick.

155. **Dense** tiling is stronger than porous tile, but more brittle, and is made of fireclay, combined with either potter's, plastic, or tough brick clays, molded into shapes to suit various constructional purposes. While the clay is still in a moist condition, it is subjected to heavy pressure, which makes it very dense, and gives the finished material great crushing strength. The tiles are then dried and burned in a kiln like other terra cotta.

Dense terra cotta is used principally in the construction of floor arches. For use in exposed situations, it is more suitable than the other kind, and is often made with glazed outer surfaces, to prevent penetration of rain. When exposed to heat it does not endure as well as porous tiling.

156. **Concrete.**—Portland cement concrete stands fire and water tests well, and may be considered a thoroughly

fireproof material. Concrete columns have been repeatedly heated red hot, and then drenched with water, without injury.

A concrete consisting of plaster of Paris, broken brick, wood shavings, etc. is much used in Paris for fireproofing purposes. A composition made of 5 parts of plaster of Paris and 1 part of fine wood shavings, with enough water added to make a thin paste, is much lighter than ordinary concrete, and is used in one of the fireproof floor constructions to be described hereafter. Instances are given of this material being exposed to intense heat for a considerable time, the results showing that it is affected only to a depth of from $\frac{1}{4}$ to $\frac{5}{8}$ inch, and does not check or crack when water is thrown on it.

Mortars, both lime and cement, applied on metal lathing, will successfully endure a great degree of heat, and will also withstand well the action of water.

FLOOR CONSTRUCTION.

157. Formerly, fireproof floors were almost exclusively made of concrete supported on brick arches sprung between the lower flanges of **I** beams, although in some cases corrugated-iron arches were substituted for the brick. The objections to these forms of construction are that the arches and the concrete are extremely heavy, the ceilings are not level, and the bottom flanges of the beams are unprotected. Consequently, a better form of construction was sought, and the brick and iron arch methods have been largely abandoned, flat arches of dense and porous tile being substituted, with much saving in weight and more complete protection of the steelwork. Considerable improvement has been made during the past 10 years in the design of tile-floor arches, and a number of systems have been introduced. In all cases, the inventor's efforts have been directed towards securing a light and economical floor, possessing sufficient strength and affording thorough fire protection.

FLAT TILE ARCHES.

158. There are at present three methods of constructing flat tile floors in use in this country. The first is known as the *side* method, so called because, in each transverse row, the sides of the blocks abut those of the adjacent ones; the second is called the *end* method, the blocks being set end to end, at right angles to the beams; the third is a combination of the first and second, the length of the skewbacks being parallel to the beams, while the other blocks are set at right angles thereto.

159. Side Method Arches.—The original hollow-tile arches used in this country were made and set similarly to those shown in (*a*), Fig. 76, with the exception that the

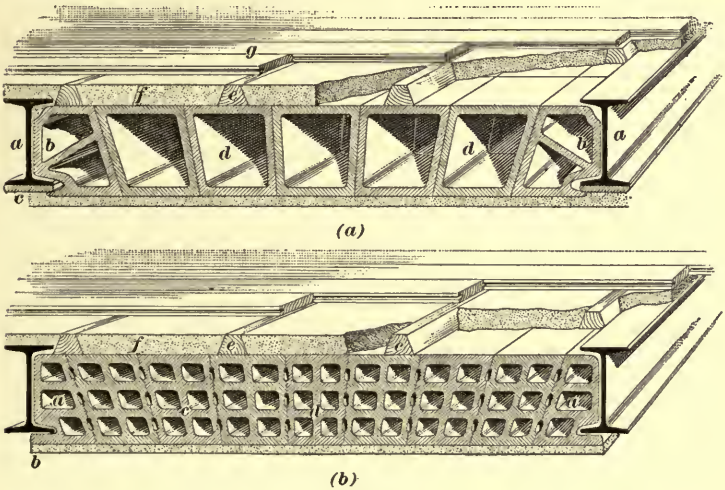


FIG. 76.

skewbacks did not extend under the beams; the latter, consequently, had no protection from fire, other than that afforded by the plaster of the ceiling. This was found to be an insufficient safeguard, as when beams protected merely by thin plastering were subjected to fire, they became twisted and warped nearly as much as though completely exposed.

An improvement was made by forming the skewbacks as shown at (*a*), Fig. 76, in which *a* shows the I beams; *b*, the skewbacks, extending below the beams; *c*, the thin pieces of tile—held in place by the skewbacks—which protect the under side of the beams; *d*, the inside blocks of the arch; *e*, the wooden strips embedded in the concrete *f*; and *g*, the flooring, nailed to the strips. When tile or cement flooring is used, these strips are unnecessary, the floor being then laid directly on the concrete.

After these arches were used for some time, it was found that they were not strong enough to sustain heavy and sudden concentrations of weight, or the rough usage floors receive during the erection of the building. To remedy such defects, the blocks were strengthened by horizontal and vertical webbing, forming a cellular structure, like that represented in (*b*), Fig. 76. Here *a* shows the skewbacks with a lower flange *b* extending to the middle of the I beam, and forming, with the adjacent skewback, a complete protection for it; *c* indicates an arch block with 6 divisions, separated by webs or partitions from $\frac{3}{4}$ inch to 1 inch thick; *d* is the center or key block; *e*, the nailing strips; and *f*, the concrete. Usually the sides of the blocks are parallel to those of the key, but arches are now made of blocks having radial joints. This is the stronger form, but is more expensive on account of the number of different pieces required. The blocks should break joint lengthwise in order to make a good bond between the sections.

Arches of the type shown in (*b*), Fig. 76, are sufficiently strong for all ordinary purposes, and, so far as known, have never failed when in actual use in buildings. Some architects, however, consider the end-method arch the stronger.

160. End-Method Arches.—Arches of this kind are usually formed of rectangular blocks, divided by vertical and horizontal webs into four or more sections, and having beveled end joints. It is not customary to make the blocks in one transverse row break joints with those in the next, as the expense of setting would be thereby increased.

Fig. 77 represents a very common type of the end-method arch; at *a* is shown the skewback, having a protective flange *b*;

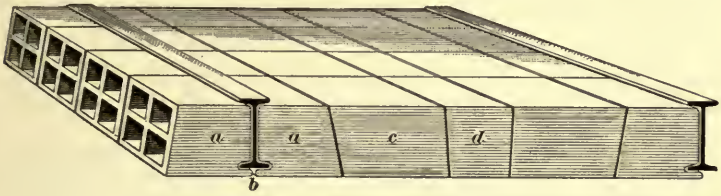


FIG. 77.

at *c*, one of the inside blocks; and at *d*, the key block. This form of construction is economical and simple, as all the blocks in each longitudinal row of the arch are made alike. Porous terra cotta is used almost exclusively in the manufacture of this type of arch.

161. One objection to this method is the increased weight, due to the thick webs which are necessary to obtain sufficient bearing to properly transmit the load to the beams. Another is that the mortar squeezes out from between the thin abutting surfaces, allowing some of the pieces to sink below the others, and rendering it difficult to secure a flat surface for the ceiling. Furthermore, if any block be broken or removed, the row will fall, there being no longitudinal bond, as in side-method arches. To obtain good bearings, the blocks should bear evenly against one another, being cut, if necessary, to set flat and give a level upper surface, and the webs should also be in line. It is recommended that solid plates be placed between the ends of the tile blocks, to form a stronger joint.

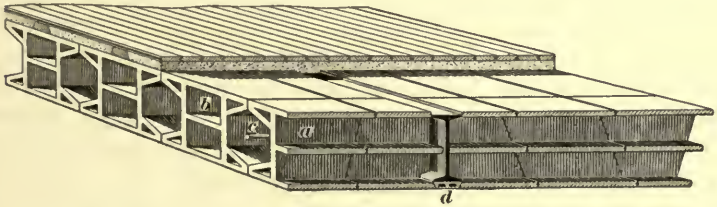


FIG. 78.

Fig. 78 shows a form of block in which greater bearing surface is provided than that represented in Fig. 77. These

blocks are made of dense tile, and have braced top and bottom flanges $\frac{3}{4}$ inch thick, the webs and central horizontal partition being $\frac{1}{2}$ inch thick. A section of the block is shown at *a*, an end view at *b*, and a tie-rod at *c*. The lower part of the I beam is protected by a plate resting on the beveled lower edge of the skewbacks, as shown at *d*.

162. Combination Method.—In this system, the object is to utilize the superior strength of the end method, and at the same time provide greater bearing surface against the beams. Whenever an arch with side-method skewbacks has

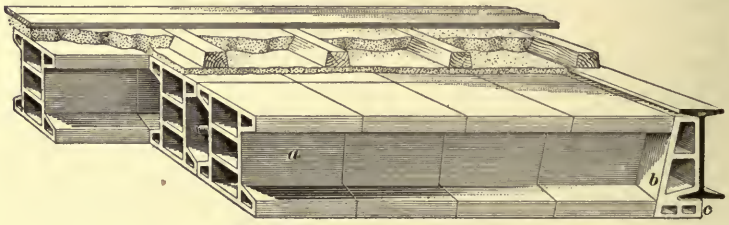


FIG. 79.

been tested to failure, it has almost invariably been these blocks that broke first; hence, it is very necessary to have them extra strong, so as to equalize the strength of the different parts forming the arch. Fig. 79 represents a form of combination construction; the inside blocks *a* are made similarly to those shown in Fig. 78; *b* is the skewback, having a flange extended under and protecting the beam, as indicated at *c*. These skewbacks have failed in some tests, and in later constructions have been replaced by those represented in Fig. 78.

163. Another combination arch, which is considered very strong and durable, is represented in Fig. 80; at *a* is shown the strongly braced skewback, having three or more webs; at *b*, the inside blocks, laid end to end; at *c*, the side-method key; and at *d*, the beam protection, formed in two pieces, and separate from the skewbacks. The side and end surfaces of the blocks are corrugated, permitting the

insertion of more mortar, and preventing the pieces slipping by each other.

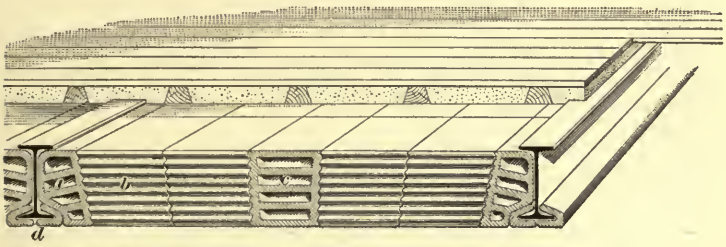


FIG. 80.

164. Weight.—The weight, of course, varies with the depth and span of the arch. The depth ranges from 6 to 12 inches in arches constructed on the side method, and from 6 to 15 inches in those built on the end method. For office and store buildings, a common depth is 10 inches, the floor-beams being spaced from 5 to 7 feet apart. It is preferable to have the blocks equal in depth to the beams, as it makes a lighter floor than when much concrete filling is necessary. The weights and safe spans of both dense and porous tiling are given in Table 4:

TABLE 4.

WEIGHTS AND SPANS OF TILE ARCHES.

DENSE TILE.			POROUS TILE—END METHOD.		
Depth in Inches.	Span in Feet.	Weight in Pounds per Square Foot.	Depth in Inches.	Span in Feet.	Weight in Pounds per Square Foot.
6	$3\frac{1}{2}$–4	22–29	6	3 – 5	21
7	4 –$4\frac{1}{2}$	27–32	7	$3\frac{1}{2}$– $5\frac{1}{2}$	24
8	$4\frac{1}{2}$–$5\frac{1}{2}$	30–35	8	4 – 6	27
9	5 –$5\frac{3}{4}$	32–37	9	$4\frac{1}{2}$– $6\frac{1}{2}$	30
10	$5\frac{3}{4}$–$6\frac{1}{2}$	34–41	10	5 – 7	33
12	$6\frac{1}{2}$–$7\frac{1}{2}$	37–42	12	6 – 8	37
			15	$7\frac{1}{2}$–10	43

The construction shown in Fig. 78 weighs less than those given here, ranging from 22 pounds per square foot in the 8-inch size to 35 pounds in the 15-inch size.

165. Strength.—There are extremely few, if any, cases on record of failure of arches in actual use, and under ordinary conditions the arches herein described are amply strong. Experimental results are sufficiently numerous, however, to be some indication of the strength of tile arches. Tests were made at Denver, Col., on two side-method arches, 10 inches deep and 5 feet in span, the blocks having one horizontal web; these gave way under distributed loads of 270 and 425 pounds to the square foot. An end-method arch of porous tile, 10 inches deep, with two horizontal webs, carried 750 pounds per square foot without failing. At Richmond, Va., tests were made of 6 and 12 inch side-method arches, the maximum load on the former being 579 pounds per square foot, and on the latter, 1,057 pounds; the average strength of nine 12-inch arches was 858 pounds per square foot. Record is made of a 15-inch arch, similar to that shown in Fig. 79, having carried 3,287 pounds per square foot before failure.

The *cost* of flat tile, laid on large areas, varies, according to depth and weight, from 15 to 25 cents per square foot of floor.

166. Setting.—To support the blocks during laying, a firm centering is needed. A good form, shown in Fig. 81, is made of 2-inch planks *a*, dressed and set closely together and resting on $2'' \times 4''$ or $2'' \times 6''$ pieces *b*, which extend parallel to the beams, and midway between them. These are suspended by T-headed bolts *c*, from similar pieces *d*, laid across the top of the beams. The tiles forming the I-beam protection are first put in place; if separate pieces, they are laid on the planks directly beneath the beams; or, if the I beams are protected by the skewbacks, as at *e*, the latter are set. The bolts are then tightened so as to slightly bend the planks, forming the slight camber, which crowning should be about $\frac{1}{4}$ inch for a 6-foot span. In setting the

blocks, the pieces should be adjusted so that the surfaces abut properly. Only the best cement mortar should be used, and the joints should be thin, but care should be used that the mortar does not become pressed out. The centering should be kept in place until the mortar joints between the blocks have set, which takes from 12 to 36 hours. When

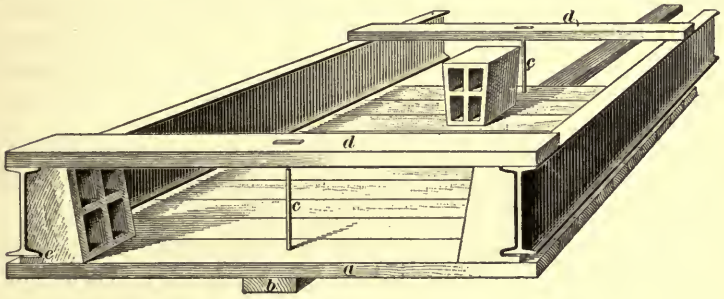


FIG. 81.

it is removed, the arch should have a level surface, showing no open joints or projecting blocks. Should there be any necessity for holes in the floor, they may be punched in the blocks, the holes being afterwards closed with broken tile and mortar; or, if the side-method arch is laid, a block may be omitted temporarily.

The design of the floors often necessitates variations in the placing of the I beams, so that some arches are longer than others. This may be provided for by using blocks of various sizes, in preference to cutting them to fit. Numerous kinds and sizes of skewbacks are also made for different I beams.

167. Tie-rods are necessary in all floor arches, to prevent spreading of the beams. They are placed from 5 to 7 feet apart, and are generally $\frac{3}{4}$-inch rods, threaded at the ends, with nuts to take up the thrust of the arch. They should be placed in the web of the beam, as near as possible to the lower flange.

168. Like all other masonry work, floor arches should not be laid in cold weather, unless ample protection is provided against injury by rain and snow; otherwise, the mortar

is likely to be alternately frozen and thawed, causing the joints to rupture and leading to the displacement of the blocks.

Until the mortar in the joints has set, care should be exercised in placing loads upon the arch. Precautions should also be taken to prevent the bottoms of the tile becoming stained, as the moisture in the mortar, unless thoroughly dried out, carries down the dirt and causes discoloration of the ceiling. It is advisable to apply some waterproof material to the under side of the arches, before laying the plaster on them.

169. Ceilings.—Before plastering the ceiling under flat arches, any inequalities should be filled with mortar, so as to make a flat surface. It is usual to apply two coats of plaster directly to the under side of the arches. If furring is necessary for fastening decorative work, etc., it may consist of either wood or metal strips, attached by bolts to the bottom of the arches, and covered with wire lathing.

170. Floors.—In nearly all systems of construction, concrete filling is laid upon the tile, to level up to the top of the **I** beams; upon the latter are then placed nailing strips, or sleepers, usually 16 inches apart, to which the flooring is fastened. These are made of thoroughly seasoned pieces about 2 inches thick, 4 inches wide at the bottom, and 2 inches at the top. Sometimes $3'' \times 4''$ pieces are used, the under side being notched 1 inch, to fit over the upper flange of the beams. A common practice is to allow $3\frac{1}{2}$ inches between the top of the **I** beams and that of the floor, in order to insert water and gas pipes, electric wiring, etc. The strips are usually laid at right angles to the beams, and fastened to them by iron clamps, one end of which is hooked under the top flanges, and the other driven into the side of the strip. If the strips are laid parallel to the beams, pieces of flat iron, about $\frac{1}{8}$ in. $\times 2$ in. and 1 foot long, are nailed across the under side of the strips, about 4 feet apart, to hold them firmly in place. When the sleepers are laid, concrete is filled in between them, flush with the tops, the beveled sides of the strips holding them in position.

171. As lightness is of prime importance in floor construction, the concrete should weigh as little as is possible for good work. This result may be obtained by using some light, porous material, such as cinders, etc., in place of broken stone. The cinders, free from dirt, should be mixed with cement or lime mortar, and the concrete should be laid compactly on the arches, being allowed to dry before the flooring is laid. To save the time required for drying, the cinders are often put on dry, but this is a practice not to be recommended. When the beams are very deep, tile of a less depth is sometimes used, and the filling consists of partition tile or specially made ∩-shaped tile.

Office buildings frequently have a great many movable partitions, to suit the requirements of tenants. In such cases, the wooden floors are laid over the whole floor space, and the partitions placed on them; but, if the latter are to be permanent, they should be put in position before the floors are laid.

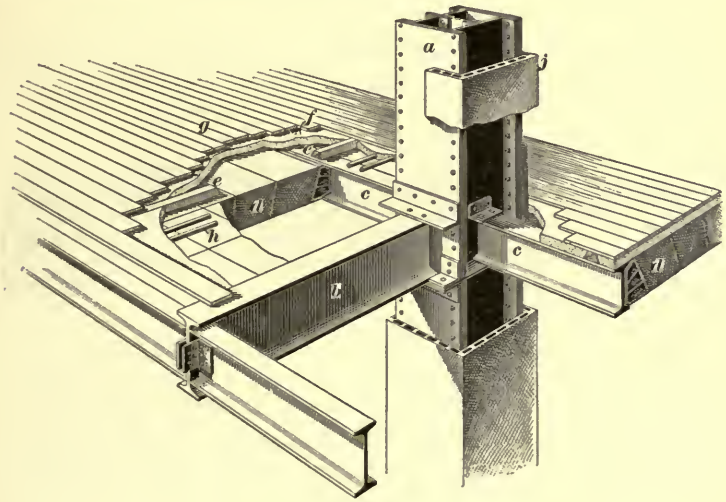


FIG. 82.

172. Fig. 82, representing the floor construction in a large Chicago building, well illustrates the foregoing descriptions. At *a* is shown the steel column, formed of Z bars and

plates, carrying the girder *b*, and the floorbeams *c*; at *d* are the tile arch blocks; at *e*, the $2'' \times 4''$ nailing strips; at *f*, the concrete filling; at *g*, the wooden flooring; at *h*, the water and gas pipes; and at *j*, the tile fireproofing and plastering around the column.

SEGMENTAL TILE ARCHES.

173. When flat ceilings are not required, as in warehouses, etc., tile arches of the forms shown in Figs. 83 and 84 are generally used, the plaster being applied directly to the under side of the blocks. The bottom flanges of the beams are protected either by plaster laid on wire lathing or by properly shaped skewbacks. This kind of arch makes very strong floors, and is much cheaper than flat tile arches. Segmental arches have been built in spans up to 20 feet, thus saving considerable weight in the columns and beams, as in such cases many of the latter may be omitted which would otherwise be required for short spans.

174. The ordinary segmental tile arch consists of blocks from 4 inches to 8 inches deep, and about 1 foot long, the rows being laid with joints broken longitudinally. The rise

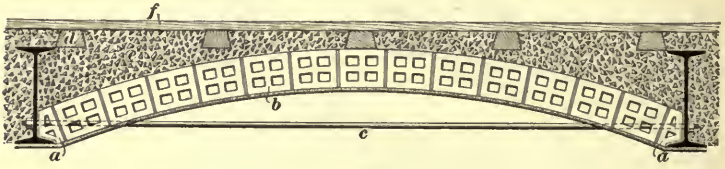


FIG. 83.

of such arches should be about one-eighth of the span, if possible, and, in any case, not less than one-twelfth. Fig. 83 shows a common segmental tile arch, *a* indicating the skewbacks, *b* the hollow inside blocks, and *c* the tie-rod taking up the thrust of the arch. This rod should be placed near the lower flanges of the beams, and be well protected by special tiling, or by metal lathing and plaster. At *e* is shown the concrete filling; at *d*, the nailing strips; and at *f*, the flooring.

Fig. 84 shows a hollow-brick arch, suitable for spans up to about 8 feet; it is similar in most respects to that represented in Fig. 83, but the skewbacks *a* have flanges to pro-

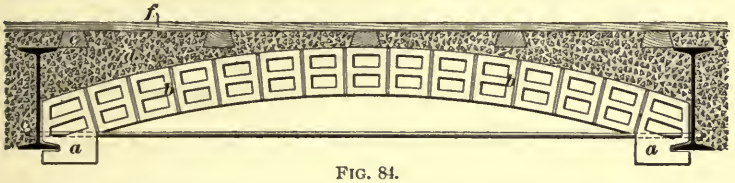


FIG. 84.

tect the I beams, and the tile blocks *b* are only ribbed one way; *d*, *e*, and *f* indicate the concrete, nailing strips, and flooring, respectively.

175. Weight.—The weight per square foot of segmental tile arches, exclusive of concrete and plastering, is about as follows:

Depth.	Safe Span.	Weight.
4 inches.	8 feet.	20 pounds.
6 inches.	16 feet.	30 pounds.
8 inches.	20 feet.	40 pounds.

The tile may be had of either dense or porous tiling; the latter is lighter and equally as strong as the former, and, consequently, is preferable to the dense kind.

The weight of the concrete depends upon its composition, and varies from 120 to 140 pounds. The plastering may be estimated at from 6 to 8 pounds per square foot.

176. Strength.—The strength of segmental tile arches, properly constructed, is practically only limited by the safe load for the beams. An arch of porous tile, having a 15-foot span and a 16-inch rise, the central 7 feet 8 inches being 6-inch blocks, and the remainder 8-inch, was loaded on one side by placing on it a pile of bricks; when the weight reached 1,235 pounds per square foot, the unloaded portion buckled and collapsed. A common brick arch of 8-foot span,

10-inch rise, and 5½ inches deep, failed by buckling under an eccentric load of 885 pounds per square foot.

177. Setting.—Segmental arches are laid in the same way as flat arches, with the exception that the centers are suspended on hooks from the beams, and can be raised or lowered by nuts threaded on the lower end of the hook-rods.

VENTILATED FLOORS.

178. In Fig. 85 is shown a system of floor construction, which is known as the *Fawcett ventilated floor*, by the use of which a saving of one-quarter of the dead weight is effected.

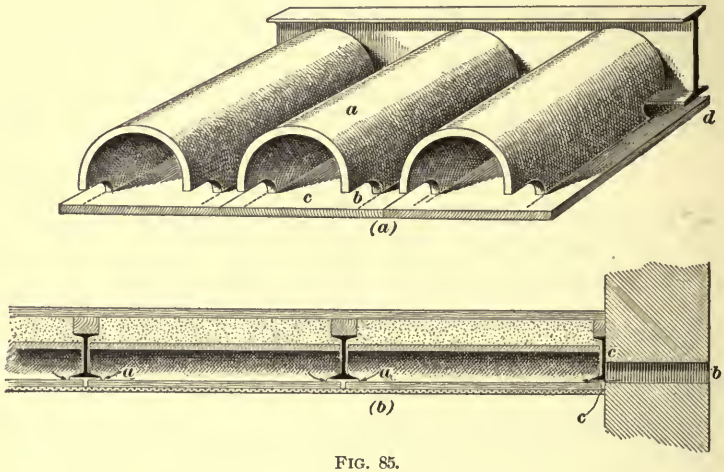


FIG. 85.

The pieces are made of dense fireclay tile, the upper part *a* being semicircular, and cut, as at *b*, to rest on the beams; this cut-out is sufficient to leave a ½-inch air space between the beam and the flat under surface *c*, which extends to the middle of the support, as at *d*, forming, with the air space, a thorough protection; the under side of *c* is grooved so as to form a good key for the ceiling plaster. For this floor, the beams are spaced 2 feet apart, more being required than with other systems. Owing to this close spacing of the beams, very light ones can be used, 5 inches being the usual

depth for spans not over 15 feet; the floors can, therefore, be made considerably thinner than in other systems; 10 inches is the total thickness of a floor having 5-inch beams. This is an important saving, amounting to 6 or 8 inches on each story. Another advantage is that these floors can be laid without centers, and by ordinary laborers.

When the tiles are laid, concrete is placed on them, resting on the lower flange of the I beams, between the curved parts of the tile; when set, the concrete between each piece acts as a beam, transmitting much of the floor load directly to the steel framing.

The great advantage of this system is the thorough ventilation afforded by the peculiar form of the tiles, the interior spaces being in continuous connection with the external air, which is admitted through air bricks in the outer walls. At (*b*), Fig. 85, is shown a longitudinal section through the tile, showing clearly the air spaces *a*, the hollow brick *b*, and the method of supporting them at the walls, as at *c*.

CONCRETE AND METAL FLOORS.

179. Concrete containing iron or steel wires, rods, netting, etc. embedded in it, is now extensively used for floor construction, and in many respects is equal to tile-arch floors, and is cheaper. One form consists in the use of wires or bars to suspend the floor from wall to wall, or between girders, taking up the tensile stress which the concrete itself is unable to withstand. Another method is to support the concrete on wire netting, or expanded metal, fastened to the beams. The earliest form of concrete floor was the *Hyatt system*, in which thin plates of iron, set upright, and bound together at short intervals by wires—thus forming a kind of gridiron—were placed in the concrete near the bottom, and rested on the beams at both ends.

180. The Ransome Floor.—From the Hyatt floor, above mentioned, was developed the *Ransome floor*, the difference being in the use of twisted square bars of iron or steel, instead of flat bars set on edge. Owing to the twisting

throughout the length of the bars, they are held firmly in place in the concrete, and are as strong as the plates and wire, besides costing much less. These floors have been used without intermediate supports for spans up to about 35 feet, and are remarkably stiff under heavy loads. A floor 15 ft. × 22 ft. was loaded for a month with a weight of over 400 pounds per square foot, the resulting deflection being only about $\frac{1}{8}$ inch.

In Fig. 86 (*a*) is shown the ordinary Ransome floor, *a* being the concrete, and *b* the twisted bars, inserted near the bottom of the slab, to take up the tension.

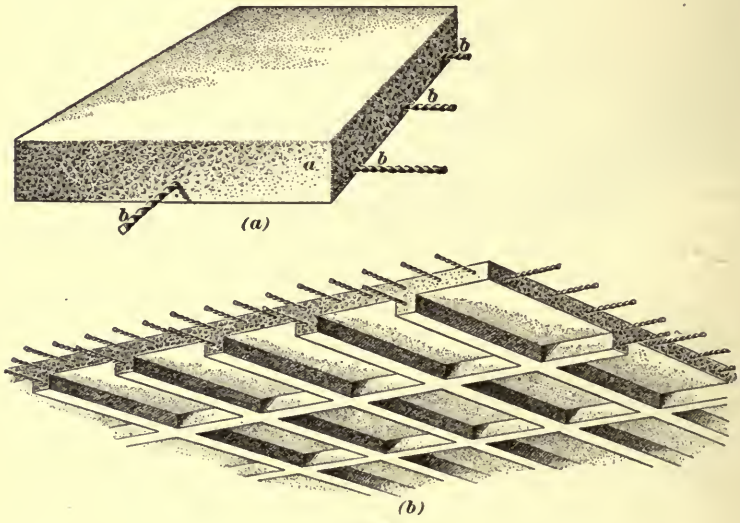


FIG. 86.

Fig. 86 (*b*) shows the same system applied to a panel floor, which is considerably stronger than the flat form.

181. The Lee Floor.—Another method of floor construction, in which use is made of iron or steel rods, is shown in Fig. 87, and is known as the *Lee floor*. In this system, hollow tiles *a* are substituted for concrete, and are supported by round rods *b*, two or more of which are twisted together, the ends being attached to the walls or girders. Quarter-round grooves are formed in the lower corners of the tiles

for the cables, which are spaced from 8 to 12 inches apart, depending on the size of the tile. When in place, the cables

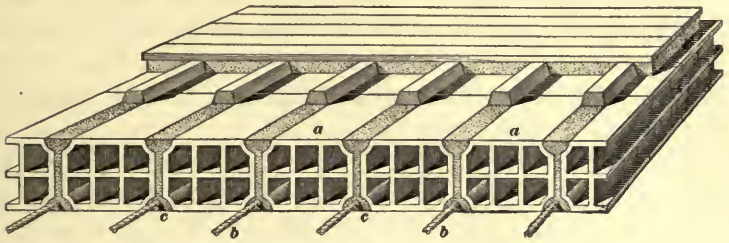


FIG. 87.

are covered with cement concrete *c*, which, with the plaster, forms an effective protection.

182. The Metropolitan Floor.—This system is shown in Fig. 88. At (*a*) is shown the first stage of construction. Light cables, spaced from 1 inch to $1\frac{1}{2}$ inches apart, and consisting of two No. 12 gauge galvanized-iron wires twisted together, as shown at *a*, are attached to the upper flanges *b* of the beams by means of hooks, shown at *c*, about 3 inches long, and made of $\frac{1}{4}$-inch square iron. In order to stretch the cables equally, a bar or pipe is laid centrally between

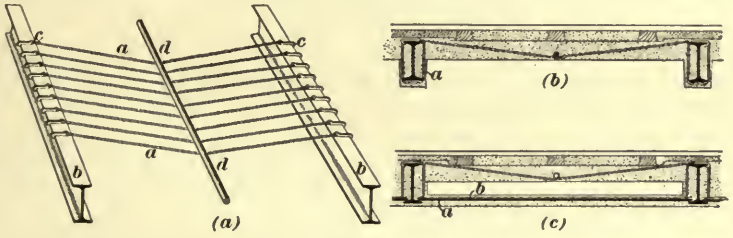


FIG. 88.

the **I** beams, as shown at *d*. Centers are then suspended, under the cables, and a composition made of 1 part of wood shavings and 5 parts of plaster of Paris, mixed to a thin paste with water, is then applied. This sets very quickly, and the floor is sufficiently strong to be used soon after it is formed. In this system the beams require no tie-rods, as floor loads, being transmitted vertically, cause no side thrust, as do arches, while the tendency to pull over the top of the

beams is counteracted by the rods and hooks in the adjacent panels. The ordinary thickness of this floor is 4 inches, the floorbeams being spaced about 5 or 6 feet apart. As the beams are generally more than 4 inches deep, wire netting is wrapped around them, as shown at *a* in (*b*), Fig. 88, to hold the plaster of Paris composition, which surrounds and effectually protects the beams.

At (*b*) is shown the completed floor, with a panel ceiling beneath. When a flat ceiling is desired, it is made as represented in (*c*), Fig. 88; *a* shows a flat bar, set on the lower flange of the **I** beams, and carrying the wire netting *b*, that serves as a support for the ceiling composition, which is laid on forms placed under the beams. The thickness of this coating is about 1½ inches, 1 inch being below the lower flanges of the beams.

183. This floor has a great many points of superiority over other floors, the chief ones being its lightness and strength. The average weight of the plate forming the floor is 18 pounds per square foot, and that of the ceiling plate, exclusive of plastering, 6 pounds. The great saving in weight may be seen by comparing these figures with those for dense tile arches, given heretofore.

The breaking load on a floor of this kind is about 1,500 pounds per square foot, with plates 4 inches thick and 6 feet span. In some instances as much as 2,000 pounds per square foot have been carried safely. This floor construction is entirely fireproof, and, on the whole, is one of the very best systems yet introduced.

184. The principle of the Metropolitan floor is utilized in other constructions, which, however, make use of cement concrete in place of plaster, and expanded metal or wire netting instead of wire rods, to resist the tensile stress.

In all floors made of concrete, plaster, or tile, with steel or iron tension rods, the two materials should be closely united, so that the bars or wires will not draw through the concrete, and thus destroy the rigidity of the floor. For this reason, the bars in the Ransome floor, and the wires in the

Metropolitan floor, are twisted, and wire netting, etc. provided in other forms, all serving to resist the slipping tendency. Furthermore, to obtain complete adhesion of concrete to metal, it is necessary that the materials and workmanship be first class in all respects.

185. The Roebling System.—In this floor, the concrete is used as an arch, and not as a beam. The method of construction is shown in Fig. 89. The first step is to spring between the beams an arch of wire cloth, shown at *a*,

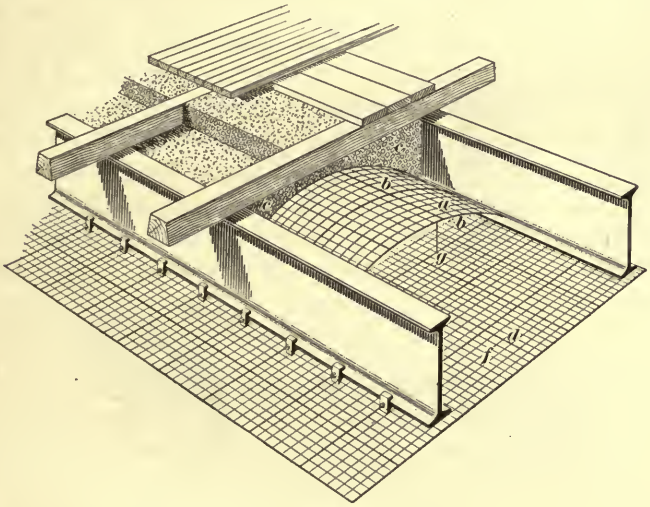


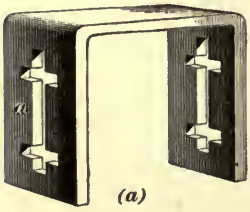
FIG. 89.

stiffened at short intervals by steel rods *b*, the ends of the arch resting on the lower flanges of the beams. On this base is laid the arched concrete filling shown at *c*, which, on becoming hard, transmits the loads directly to the beams. The ceiling is held by a similar netting of wire *f*, fastened to stiffening rods *d*, which are attached to the lower flanges of the beams by clamps, and also to the arch netting by tie-rods, as at *g*.

This floor weighs, exclusive of beams, but not including the ceiling and two thicknesses of wood flooring, from 47 to to 59 pounds per square foot, according to the span. The carrying capacity is from 1,000 to 2,400 pounds per square foot, on spans of from 4½ to 5 feet.

The Roebling floor possesses the following advantages: first, a flat ceiling; second, a continuous air space between the floor arch and the ceiling; third, its lightness as compared with most tile ceilings; fourth, the ease of adaptation to any building or any load; and, lastly, no wood centerings are necessary—the wire arches forming the support for the concrete during the laying.

186. The **Columbian system,** shown in Fig. 90, resembles somewhat the Metropolitan floor, but with the difference that the concrete, instead of being stiffened and supported by wires, is carried on steel bars, having the section shown at *a*, in (*a*), Fig. 90; these are inserted in similarly shaped openings in the stirrups (*a*) which set over the I beams. The bars are from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches deep; the 2-inch bar is the usual size for office buildings, the $2\frac{1}{2}$-inch bar being used for warehouses,



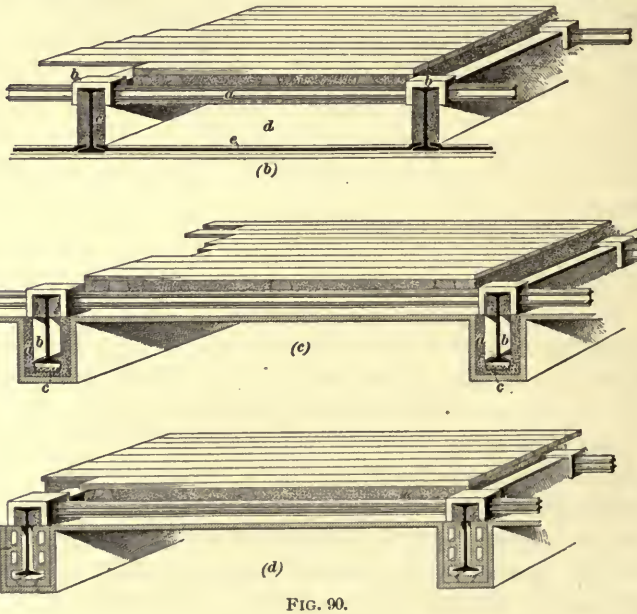


FIG. 90.

etc. The stirrups are usually spaced about 20 inches apart, and are made of $2'' \times \frac{3}{16}''$ steel plate. The spacing of the floorbeams is from 5 to 6 feet, and as the loads are transmitted vertically, no tie-rods are required.

When the bars are in place, forms are hung beneath them, and a layer of cement concrete is formed, completely embedding the bars. On this the flooring is laid in the usual manner.

187. In (*b*), Fig. 90, is represented the construction when a flat ceiling is desired. At *a* is shown the ribbed bar; at *b*, the steel stirrup; at *c*, the concrete casing of the floorbeams; at *d*, the air space; and at *e*, the 1-inch bar laid on the lower flange of the I beams, and forming the support for the ceiling, which is put on similarly to the floor layer. In (*c*), Fig. 90, are shown the I beams encased in slabs of concrete *a*, with air spaces, as at *b*, on the sides and under the beams. At *d*, in (*d*), is shown a beam protection made of hollow tile. Both the concrete and the tile are fastened to the beams by clamps or ties, as at *c*, in (*c*), which are well protected by the casing.

188. The safe loads and weights of this floor, per square foot, exclusive of I beams, plastering, and flooring, are as follows:

Depth of Bars.	Span.	Thickness of Concrete.	Weight, Lb. per Sq. Ft.	Safe Load, Lb. per Sq. Ft.
$2\frac{1}{2}$ inches.	6 feet.	4 inches.	40	600
2 inches.	6 feet.	3 inches.	30	200
$1\frac{1}{2}$ inches.	5 feet.	$2\frac{1}{2}$ inches.	24	150

The level ceiling shown in (*b*), Fig. 90, weighs about 20 pounds per square foot.

As an instance of the strength of this floor, it is said that a mass weighing about 240 pounds was dropped several times from a height of 8 feet, upon the middle of an 8-foot span, without causing any injury to the floor.

SELECTION OF A FIREPROOF SYSTEM.

189. The question of choosing the best floor system out of the many of nearly equal merit, hinges largely on the cost, as any of those that have been described will be found amply strong and thoroughly fireproof, if constructed properly. Although, perhaps, the greater number of architects prefer the use of arch tile floors, the combinations of concrete and steel and iron are much used; such floors have passed through the experimental stage, and have shown that they make a very strong and thoroughly fireproof construction. Other things being equal, the floor that is lightest is the best, as the weight and size of beams, girders, columns, etc. may then be considerably lessened, which is an important factor in the cost of the structure. Where strength is the object sought, those floors should be used which have shown sufficient strength to meet the requirements of the case. In all floors, the character of the workmanship, and the quality of the materials used, have a great deal to do with the durability and efficiency, and hence should receive careful attention during construction.

FIREPROOF ROOFS.

190. **Flat Roofs.**—The roof of a fireproof building is usually flat, with a pitch of from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch to the foot. The advantage of a flat roof is the ease of making it fireproof, and also the smaller cost as compared with pitch roofs. The roof is built in the same manner as tile floors, the tiling being carried on light T or I beams, and the supporting columns having a lighter section than those under the floors.

When the tile or other material forming the bearing surface is in place, it should be plastered over with cement mortar, to give it an even face, ready for the exterior covering. The latter may be either of tile, set in cement, or of tar and gravel, asphalt, copper, iron, or tin. The use of porous tile is recommended when copper or tin coverings are to be used, as nails may be readily driven into it. A very essential point is that the bottom flanges of all I or T

beams be completely enclosed by fireproof materials; when tiling is used, a heavy coat of plastering should be placed on it, especially under the beams. All supporting girders and columns should also be well protected, either by hollow tiling, or by plastering on metal lathing.

191. Mansard and Pitch Roofs.—For mansard and other roofs having a very steep pitch, the usual construction consists of I beams set from 5 to 7 feet apart, the intervening spaces being filled with 3-inch hollow partition tile. If slate is to be used in covering, nailing strips are fastened to the tile, and the surface is brought up flush with cement mortar, upon which the slate is laid. The strips are unnecessary, of course, if porous tiling is used. For roofs having less than 45° pitch, plates of porous tile, supported on 3″×3″ T beams, are very satisfactory. All parts of the ironwork should be well protected from fire by casing them in porous tiling or wire lathing, covered with a thick coating of plaster.

192. Ceilings under flat roofs are usually similar in construction to those beneath the floors, but all parts are made quite light. Under pitched roofs, however, when a flat surface is necessary, the ceiling is usually suspended by rods attached to the roof framing. These carry angles or T bars, to which is fastened the wire netting holding the plaster. Such ceilings weigh about 12 pounds per square foot, exclusive of iron.

Sometimes light tiling is used instead of the metal lathing, in which case the porous variety is the best. In Fig. 91 is

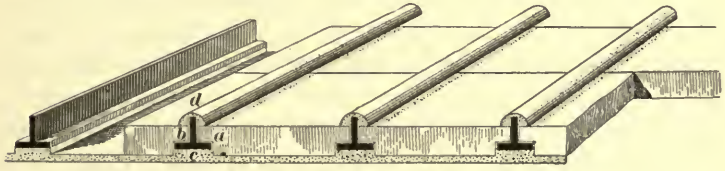


FIG. 91.

shown a ceiling with porous tile *a* carried on T bars *b*. The under side of the bars is protected by plaster *c*, while the top of

the web is enveloped by cement mortar *d*. The tiles are from 2 to 3 inches thick and from 16 to 24 inches long, weighing from 11 to 15 pounds per square foot, not including plastering.

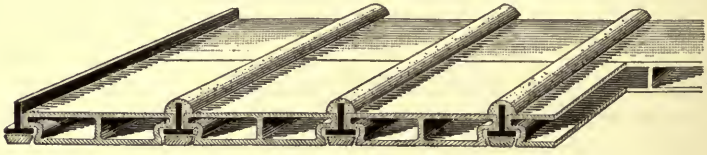


FIG. 92.

Fig. 92 shows a ceiling made of hollow tile, laid on T bars, with plates to protect the flanges.

PROTECTION OF COLUMNS AND GIRDERS.

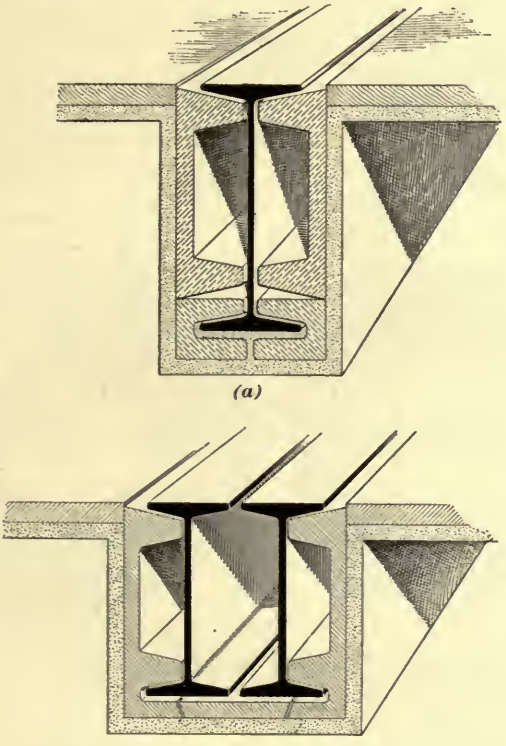
193. In case of fire, the columns and girders in a building are naturally more exposed to heat than are other parts of the structure, and, hence, should be most amply protected, as the effect of fire on ironwork is very severe. There are two general methods of protection in common use: one consists in the use of tiling, and the other of concrete held in position by metal lathing, etc. Usually the girder and column protection is accomplished by the use of the same material that forms the floors. As porous tiling is one of the very best fireproof materials known, it is highly recommended for use as a cover for the ironwork. If wire lathing is wrapped around the tiling, the liability of the blocks becoming displaced during a fire is much decreased.

194. Girders.—In (*a*) and (*b*), Fig. 93, are represented two common forms of casings for girders which extend below the floorbeams. These are made of solid porous tile; when dense tile are used, it is best to make them hollow, as shown in (*c*), Fig. 90. The blocks are held in place by clamps or ties, not shown.

Girders are sometimes wrapped with metal lath, upon which the plastering is applied. This subject will be taken up under "Plastering."

195. Columns are usually rendered fireproof by enclosing them in either dense or porous tiling. The former is

probably the most used for this purpose, but is not as effective under the action of fire as the porous variety. The pieces are fastened to one another by concealed metal ties,



(a)

(b)

FIG. 93.

or by wrapping the casing with wire or metal lathing. The casing is set away from the column, around which an air space is thus left.

Concrete is also used to protect columns, either applied as a solid covering, or as a shell a few inches thick around the pillars, leaving an interior air space. Plaster applied to wire or expanded metal lath is another method of protection, and will be explained under "Plastering."

196. The Chicago building law makes careful provision in regard to fireproofing columns, and its requirements will

serve as a guide to proper construction. If brick is used as the protective casing, it must be at least 8 inches thick; if tile is used, it must be put on in 2 rings, each at least 2 inches thick for porous terra cotta, or 2½ inches thick for dense hollow tiling. The two thicknesses of tile must break joint, and must be so fastened as to be independent of each other. If the covering is likely to be injured by trucking, etc.—as in a warehouse or store—the lower 5 feet must be cased in hardwood planks or sheet iron.

197. In Fig. 94 is shown the method of arranging solid

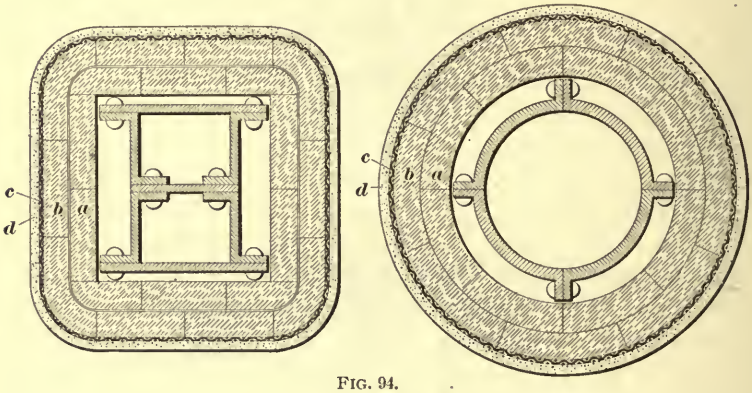


FIG. 94.

porous tile around both square and round columns. In each case, *a* and *b* represent the first and second layer, respect-

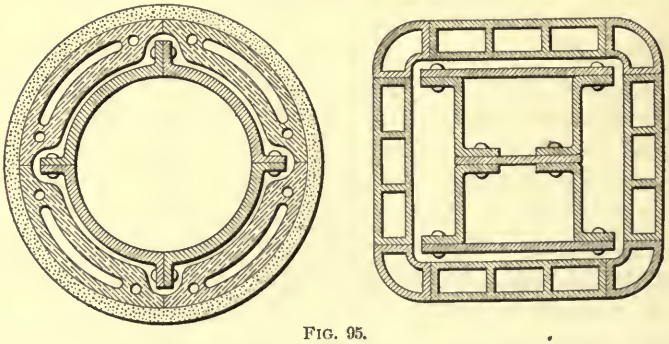


FIG. 95.

ively; *c*, the wire or expanded metal lathing binding the

pieces together; and *d*, the plastering. In Fig. 95 are shown similar columns, encased in dense hollow tile.

198. The space between the column and casing is generally utilized for placing gas and water pipes, electric wiring, etc., but a better method is to provide another passage adjacent to, but independent of, the column. In this way, if there is occasion to repair the pipes, it will not be necessary to displace the column protection, which might not be put back in perfect condition. The plan mentioned is shown in Fig. 96.

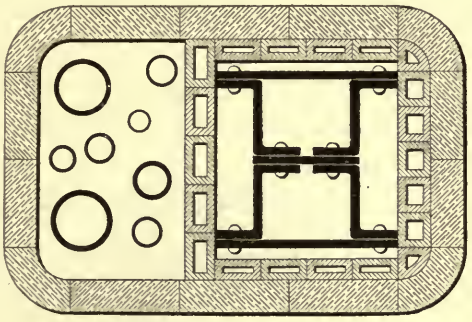


FIG. 96.

FIREPROOF PARTITIONS.

199. Fireproof partitions are usually made of tile, or wire lathing or plaster, although brick and iron are used to some extent. The objection to brick is that it must be at least 1 foot thick in order to be thoroughly fireproof, and this causes unnecessary weight. If iron is used, it must be well protected. If the partitions are of tile, they are quite thin and light, and may be readily removed and set up elsewhere, to suit the requirements of tenants. The tile may be either of the dense hollow, or porous kind, and may vary from about $1\frac{1}{2}$ inches to 6 inches in thickness; the usual thickness, however, is 4 inches, with face dimensions of 6 in. × 12 in., or 12 in. × 12 in. Porous tile are preferable on account of their greater fire-resisting qualities, and also because they hold nails well; with dense tile, wooden nailing strips are necessary. If the tiles are hollow, they may be laid with the voids extending vertically or horizontally. If laid in the former way, the tiles are usually tied together by clamps, as the mortar joint is not very effective. If set

horizontally, the mortar is spread over a much larger surface and makes a better joint. The blocks are usually set in lime mortar containing about $\frac{1}{4}$ part of cement. "Acme" cement plaster is also considerably used, as it sets quickly and adheres well to the blocks.

200. Special recessed tile are provided to receive the pipes which it is necessary to run along the partitions. These are shown in Fig. 97, in which *a* shows the ordinary

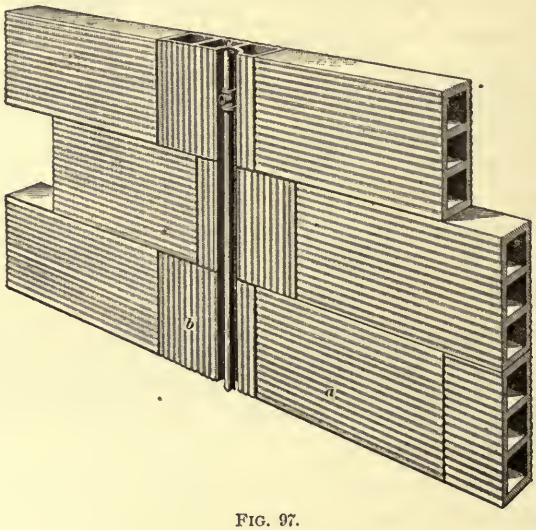


FIG. 97.

tile, and *b* the special tile, grooved to permit the insertion of pipe *c*.

Wherever doors or other openings come in the partitions, as shown in Fig. 98, the tile *b* abuts rough wood frames *a*, to which the finished casings *c* are nailed.

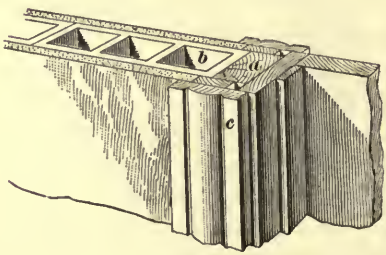


FIG. 98.

201. When extremely thin partitions are required, they are usually made of very small angles or beams, to which is attached wire or

expanded metal lath. Porous terra cotta, in pieces 2 inches thick, is also used, being bound together by metal clamps, and similarly attached to the floor and ceiling. In another form, the blocks are held in place on both sides by light steel rods, which are fastened at the ends, and enclosed throughout their length by the plaster. For rooms under 13 feet in height, the last mentioned partition is only 2 inches thick, increasing to 4 inches for a height of 20 feet. Another kind of thin partition is made on the principle of the Ransome floor, of concrete, supported and stiffened by twisted bars, as described in "Concrete Construction."

202. The average weight of hollow tile partitions, including plastering on both sides, is from 27 to 36 pounds for 3 to 6 inch thick dense tile, and from 24 to 39 pounds for the same thickness of porous tile.

203. **Wall Furrings.**—Basement walls of fireproof buildings are generally protected by hollow tile. The method of laying these will be found under "Terra-Cotta Furring," in *Masonry*, § 7.

PLASTERING.

204. **Plastering** may be described as a process of clothing the structural members, which compose the skeleton of the building fabric, with plastic material so as to render it more agreeable and habitable. This process is applicable to both the exterior and the interior of the structure. When used for exterior work, as in overlaying an inferior grade of stone or brick masonry, or in forming the covering material or wall sheathing to protect the framework, it is usually classified as *stucco work*.

Improved processes in the manufacture of brick and terra cotta, increased facilities for handling and cutting stone, and the desire for truthful construction, have all acted to drive stucco work out of the field; so strongly has this reaction influenced the public mind that the term *stucco* has become

synonymous with everything that partakes of a spurious construction and fraudulent concealment. This change in public taste has practically limited the exercise of the plasterer's art to interior work. In this restricted sphere, however, there is ample opportunity for the exercise of good, honest, and skilful work, as no other substance has yet been produced which so well satisfies the requirements in the treatment of the large areas which occur in interiors.

The natural march of progress, and especially the introduction of modern fireproof construction, has led to the development of new methods and the improvement of old ones, so that at present the art of plastering has reached a high degree of perfection. To obtain such results, the prime requisites are good materials and workmanship. As these depend greatly upon the specifications, it is necessary that the architect be well acquainted with the nature and qualities of the materials, and the proper methods of performing the work, in order to be able to intelligently make such specifications, and to see that they are properly carried into execution.

LATHING.

205. As plastering consists in the application of a plastic material called *mortar*, composed of various substances, and which is spread over the surfaces of the walls and ceilings in thin layers, the surface to be covered should present every facility for the perfect adhesion and retention of the material which is to be applied. Generally speaking, there are only two kinds of bases that are coated with plaster, and built up with subsequent layers to form a mass of sufficient thickness to withstand pressure, and to retain a true and uniform surface. The first may be called a *lithic*, or stone, base, and the second a grille base. In the former case, the plaster is laid directly on the face of the naked wall, which may be of either stone or brick; in the latter, it is spread over a grille-like arrangement of wood or metal strips, the edges of which are sufficiently separated to allow the mortar to pass through the spacing between them, and fold over on the

inner face, thus forming a *key*, or continuous clinch, which will effectually hold the mortar in position.

206. Lathing is the general term applied to the grille base above mentioned, and generally consists of wood in non-fireproof buildings, like ordinary frame dwellings, and of metal in fireproof structures. Although not absolutely necessary on brick and stone walls—as plaster adheres well to such surfaces—it is usually better to have some kind of lathing on exterior walls built of masonry; by this means the plaster slabs are isolated from the wall, and a clear air space intervenes. This insures a continually dry surface, which would otherwise be liable to dampness, from the condensation of the heated air of the room on the cold surface of the walls, or from moisture penetrating the body of the wall during a period of wet weather.

Lathing on exterior brick or stone walls is usually attached to vertical strips, 1 inch thick by 2 inches wide, called *furring*, which have been fixed to the walls by the carpenter; these strips are set at 12-inch or 16-inch centers, according to the grade of the work. In the case of walls in frame buildings, the lath is attached directly to the studs, or vertical posts, which form the framing of the walls. The ceiling lath may be nailed directly to the under edges of the joists, or it may be attached to *cross-furring*—a series of strips, similar to those used on the walls—arranged at right angles to the joists and fixed at 12-inch centers; by the latter method better results are obtained, as the warping of the joists does not affect the lath.

WOODEN LATHING.

207. In old work, the lath was generally made of oak, but in current practice, pine, spruce, and hemlock are used. The regular size of the lath strips is $\frac{1}{4}$ in. $\times 1\frac{1}{2}$ in., and 4 feet in length; this length regulates the spacing of the furring strips, studs, and joists in order to prevent waste of material.

The lath may be either split or sawed; the former gives a

better wall, as there are no cross-grained fibers to reduce its strength; while the presence of the cross-grained fibers in sawed lath makes it liable to curl and warp, due to the absorption of moisture from the mortar, still, being somewhat cheaper, it is more generally used in this country. To avoid the warping already referred to, the lath should be straight grained; to insure durability, it should be well seasoned, free from any appearance of sap, rot, or incipient decay; for strength, it should be clear of shakes and large or loose knots; and to prevent the subsequent discoloration of the plaster, the lath should be free from live knots and resinous pockets.

Laths are sold by the thousand, which will cover about 570 square feet, estimating $1\frac{3}{4}$ laths to the square foot. A fairly good workman will put on from 1,000 to 1,200 laths per day of 10 hours.

208. The laths are nailed in place in parallel rows, the edges being kept a full $\frac{1}{4}$ inch apart, to enable the soft plaster to be pressed through and form the key. The ends of the laths should not lap over each other, but should be butt jointed and flush. Continuous joints should not occur on one support, but the lathed surface should be divided into panels from 15 to 18 inches in width, and the joints be made to break on alternate supports, as shown by the panel *a b d c*, Fig. 104; otherwise continuous cracks will be liable to form. The laths are usually attached to joists and studs with cut or wire nails, about $1\frac{1}{8}$ inches in length, and having large, flat heads, one nail being used at each support; more solid work is obtained where two nails are used at each support, but in any case there should be at least two nails in each lath at each end. The nails should be galvanized, to prevent the moisture from readily attacking the iron and causing the nails to rust, which will produce large yellow patches on the surface of the plaster. Where certain plasters, such as Keene's cement, are applied, copper nails must be used, as the plasters contain ingredients that will cause iron nails to rust rapidly.

Where joists or studs are over 2 inches in width, a strip should be attached to them so as to allow the lath to be kept clear of the wide surface and enable the plaster to form the key. Nails are sometimes thickly studded over wide surfaces of wood, such as beams, the plaster rivet being formed around the heads of the nails; but, where practicable, lath splits nailed at intervals to the beam, transversely to the lathing, will give better results. The practice of closing angles and narrow spaces with the laths placed vertically, should not be allowed, as an imperfect key is formed, owing to the weight of the mortar causing a downward flow of its substance.

209. Sheathing Lath.—A combined sheathing and lath has been used to some extent, and, while somewhat more costly, is an excellent substitute for ordinary lath. It consists of $\frac{7}{8}$-inch boards, 8 inches in width, cut in uniform lengths, and grooved as shown in Fig. 99. Such sheathing

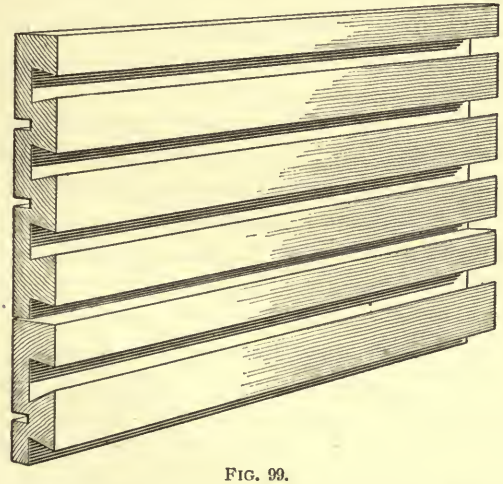


FIG. 99.

is especially valuable when the outer walls of wooden buildings are to be back plastered; that is, the sheathing, grooved side inwards, is nailed to the outside of the studs, the plaster being applied between the latter. This method makes a very warm house, but, when a second thickness of plaster is

used inside the studs, it is, of course, more expensive than the ordinary plastering. This lath is also used for inside work, and has the advantage of requiring less mortar than the common lathing, and also that nails can be driven anywhere in them without danger of loosening the plaster.

METAL LATHING.

210. Steel, in the shape of wire netting and of expanded and perforated metal lath, has come into very extensive use for the support of plastering, especially in fireproof structures. Plaster becomes more firmly attached to metal than to wood, and will not become loosened by ordinary accidents; and, as the steel is more or less completely embedded in the plaster, the latter protects it effectively from fire, whereas wood lath is only partially covered. Apart from the fireproof qualities, metal lath are of value in wood construction, from the fact that plaster laid on them will not crack nor fall off, from shrinkage in the woodwork; and, if the lath are set away from the joists and studs, these will not show through the plaster, as is generally the case when it is laid on wooden laths.

Probably the best fireproof lath consists of strong wire cloth stretched tightly over metal furrings. In the difficulty of doing this properly lies one of the objections to the use of wire cloth, as, unless the netting is quite rigid, it will yield considerably as the coats of plaster are applied; however, manufacturers now furnish stretchers, the use of which, to a great extent, obviates this difficulty. Objection has also been raised that both wire and expanded metal lath require much more plaster than wooden lathing. In this fact lies their great value, for, as the mortar is the fireproofing material, the lathing should be completely embedded in it; otherwise, thin metal is of little, if any, greater value than wooden lathing. Numerous severe tests, both experimental and in actual fires, have demonstrated that plaster—especially the hard kinds—applied to wire cloth, will successfully protect woodwork from fire, if the wood be completely covered by it.

Wire lathing may be had in numerous sizes; the most used

size has about $2\frac{1}{2} \times 2\frac{1}{2}$ meshes per square inch, and is made of No. 20 gauge wire. It comes in rolls from 32 to 36 inches wide, but some manufacturers supply it in widths up to 8 feet. The lathing may be had either plain, painted, or galvanized. The latter form, while more expensive, is preferable, as it is much stiffer and less liable to rust than the plain cloth. Painted lath is nearly as good as the galvanized, and costs considerably less.

211. Furring.—When wire lath and plaster are used to protect woodwork, they should not be in contact with it, but separated by a space of at least $\frac{1}{4}$ inch, while more is advantageous. To obtain this spacing, furring strips are necessary. These may be either woven into the wire cloth, or be separate pieces, fastened to the wood before the lathing proper is applied. In the latter case, the strips consist of corrugated or flat iron, of proper width to give the required air space when set on edge—usually about $\frac{1}{2}$ or $\frac{3}{4}$ inch—and are secured to the wood by small staples. The strips generally run lengthwise of the floorbeams and studding; if laid crosswise, they have not such a firm bearing, and should be placed closer together, or heavier strips should be used.

A substitute for this kind of furring is made of $\frac{1}{8}$-inch rods, spaced from 6 to 8 inches apart, and kept away from the wood by separators made of small pieces of thin metal, having the ends turned up from $\frac{1}{2}$ to 1 inch at right angles to the back, which is slotted to permit the insertion of staples. This furring should run across the joists, or studs, and the rods may be placed as close together as required.

212. Stiffened Wire Lathing.—The use of separate furring strips forms an item of expense that may be avoided by substituting, for the plain wire lathing, those having ribs attached or woven into the cloth. The first mentioned is the *Clinton stiffened* lath, which consists of narrow strips of corrugated steel fastened to the netting at 8-inch intervals, crosswise to the length of the roll, by means of metal clips. The lathing is nailed to the floor joists or studs with the strips next the wood, and serves to keep the cloth away from it. .

The second kind referred to is the *Roebling* lath, and is formed of ordinary wire cloth having **V**-shaped stiffeners woven into the cloth at distances of about 8 inches. These ribs are made of sheet iron, and vary from $\frac{3}{8}$ inch to $1\frac{1}{2}$ inches in depth, the former being the standard size, while the heavier sizes are used for furring exterior walls, to provide greater air space. The wire cloth is made with $2\frac{1}{2}\times2\frac{1}{2}$, 3×3, and 3×5 meshes per inch, the first being the usual size for lime-and-hair mortar, and the others being used with hard plasters.

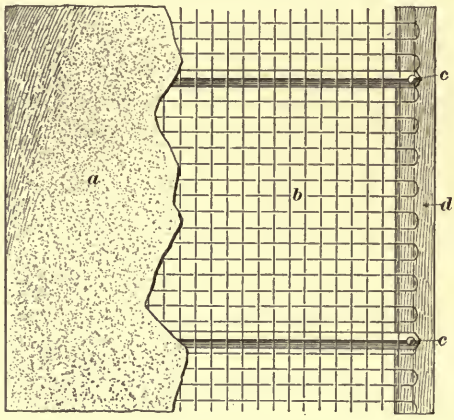


FIG. 100.

In Fig. 100 is shown the Roebling lath; *a* represents the plaster; *b*, the wire cloth, stiffened by the strips *c*, which are attached to the woodwork *d* by sharp-pointed nails driven through the point of the **V**.

213. Expanded Metal Lathing.—Fig. 101 shows a kind of metal lathing made from thin sheets of soft and tough steel, slit and expanded so that a diamond-shaped mesh is formed, with the width of the strips turned nearly square to the surface of the sheet. It may be had in two sizes of mesh, $\frac{3}{16}$ in. $\times1\frac{1}{4}$ in.

FIG. 101.

and $\frac{1}{4}$ in. $\times 1\frac{1}{4}$ in., and in sheets from 14 to 20 inches in width and 8 feet long; the thickness of the lathing is barely $\frac{1}{4}$ inch. This lath possesses considerable stiffness, and does not need stretching; it can be fastened directly to the floor joists and studding; but, when laid on boards, metal furring should be interposed. The lathing is stiffer when placed so as to have the long diagonals of the mesh at right angles to the studding, etc., to which it is fastened by 1-inch staples.

214. Perforated sheet-metal lath are made by corrugating or ribbing sheets of thin steel or iron and punching out or expanding some of the metal between the ribs, in order to afford a good clinch for the plastering. There are a number of different kinds, but the general appearance is similar to that shown in Fig. 102. The usual size of the sheets is 8 feet long by from 16 to 24 inches wide. These laths are much more easy to put on than wire cloth, and can be applied as quickly as wood lath, being especially easy to bend to fit corners (where the lathing should never be cut, but continued to the next stud beyond the angle, so as to stiffen the wall and prevent cracks at the corners). The lathing is fastened by means of barbed nails; the nailing should be started at the middle of the sheet and carried to the ends, in order to make the lathing set firmly on the woodwork.

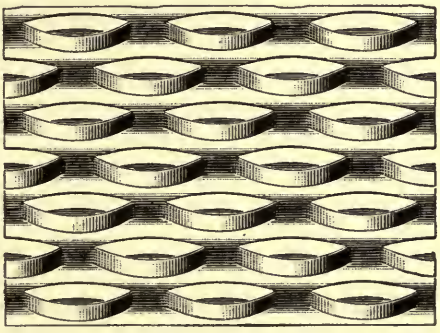


FIG. 102.

Fig. 102 shows one of the best known and most satisfactory metal laths, which is called the *Bostwick*. This is made of ribbed sheet steel, having considerable of the metal between the ribs cut and curved out; the openings are $\frac{3}{8}$ in. $\times 1\frac{3}{4}$ in., and the ribs are spaced $\frac{3}{4}$ inch apart. This lath should be put on with the raised side outwards.

215. Metal Lath in Wood Construction.—While metal lath is, of course, preferable to wood for ordinary frame structures, the additional cost generally precludes its use; but even in such buildings there are numerous places where it is of considerable advantage, while the increased expense is but little. For example, cracks at corners of ceilings and partition walls can be largely prevented by bending a strip of wire cloth, or lath, to fit the angle, and nailing it to the joists or studs on either side. Another place where metal lath should be used is at the junction of a wood partition and a brick wall, when there is no furring on the wall, and especially when the partition is flush with it. If a strip of metal lath be lapped 12 inches on both wall and partition, cracks at the junction will be avoided. Difficulty is sometimes experienced on exterior brick walls with wooden lintels, in that, when the plaster is applied, it cracks at the joint or will not stick to the wood. To obviate this, the joint should be covered with a strip of metal lath fastened to both brickwork and lintel. The above mentioned uses are only a few of the numerous valuable applications of metal lathing to wood construction; others will doubtless suggest themselves.

216. Plaster boards are made of some fibrous material embedded in plaster of Paris, and are used chiefly as a substitute for lathing and the first coat of plastering, one face of the board being grooved, or rough, to make the plaster adhere well. The usual size of the pieces is from $\frac{5}{8}$ inch to 1 inch thick, 16 inches wide, and 4 feet long. They can be readily sawed, nailed, and put on very rapidly, and are fastened directly to the studs, furring, or joists. These boards are nearly as fireproof as terra-cotta tile, and on account of their lightness and the ease of setting them, are sometimes used in place of tiling for suspended ceilings and elsewhere. As lathing and the first coat of plaster—and often the second coat—are not required when these boards are used, the saving, taken in connection with their low cost, makes them a very cheap, yet effective, kind of fireproofing.

LIME PLASTERING.

MATERIALS.

217. Up to quite a recent period, practically all the interior plastering in this country was composed of lime, sand, and hair. When plaster is made of a good quality of lime, well slaked and properly mixed with the other constituents, it is very durable; but much of the lime plaster now used is made of inferior materials, so that much of it is practically valueless as far as durability is concerned.

The substances which enter into the composition of the mortar will depend upon the nature of the surface to be coated, the order in which the layer is applied, and on the desired finish. For ordinary work, these are *lime*, *water*, *sand*, *hair*, and *plaster of Paris*.

218. **Lime** may be briefly defined as the product resulting from the calcination of the natural limestone, calcination being the process of heating the material in a kiln or oven until it emits a red glow, thus releasing the carbonic acid and moisture. The product is *quicklime;* the lumps of the material, after being removed from the kiln, are called lime shells. In preparing the mortar, the lime shells are deposited in a wood trough called the slacking, or slaking, box (so as to keep them clear of any earthy or loamy matter), and are liberally sprayed with as much water as they will absorb, when they soon begin to swell, crackle, and fall into a powdery mass. This process is called *slaking*, and the powdered substance is termed *slaked lime*, or *hydrate of lime*, from its admixture of water; during the process, the pure lime increases from two to three times in bulk, and much heat is given out, which transforms the excess of moisture into steam.

Many limes that make good mortar for other purposes, are unfit for use in plaster, as there are more or fewer overburned, hard, obstinate nodules which resist the permeation of the water, and fail to readily disintegrate; eventually they will slake, or what plasterers call "pop," causing a

small piece of plaster to fly off. Walls and ceilings may sometimes be seen pitted all over from such checking.

In many places a number of different brands of lime may be had, and care should be used in selecting one for plastering purposes, unless its slaking qualities are known. In any case, it is not best to use lime until it has been slaked at least a week, as even with the best limes considerable time is required for the slaking of all the particles.

Lime is frequently sold by weight in the Western states, but elsewhere it is usually put up in barrels and sold by measure.

219. Sand.—This should be angular, of medium fineness, and free from earthy matter. Before use, all sand should be well screened, to remove the coarse particles, and if used for hard finish, it should be sifted. Its cleanness may be tested by rubbing a small quantity between the hands; if it contains much dirt, it will stain them. Another simple method is to squeeze some of the moist sand in the hand; if it cakes together, and retains the impression of the fingers, it very likely contains clay; but if it falls apart loosely it may be considered clean. The best plaster is made of screened, washed, and dried sand. In most cases, the sand is merely screened river or pit sand; the first is the best, as the water has washed away most of the clayey matter, while pit sand is likely to contain it. Sea sand is not desirable to use, on account of the salt contained in it, and the roundness of the grains. If used at all, it should first be well washed in fresh water. The chief uses of sand in mortar are to prevent excessive shrinkage and to lessen the quantity of lime required. It also greatly strengthens the mortar, owing to the formation of a very hard silicate of lime.

220. Hair and Fiber.—These are used in plaster for the reason that ordinary lime mortar alone does not possess sufficient cohesive power to bind it together firmly. The first named is used almost exclusively for this purpose, but in the Eastern states Manila fiber, cut into short pieces, is

frequently substituted for hair. The patent ready-mixed mortars usually contain either Manila jute or asbestos as a fibrous material. Cattle hides are the chief source of plastering hair, which, after being cleaned from grease, washed, and dried, is packed in bags containing a bushel (measured loose), and weighing from 6 to 8 pounds. The hair of salted hides is undesirable, owing to the presence of salt, which is not easily extracted. Goat hair, when it can be had, is preferable to cattle hair, as it is longer and of better quality.

221. Plaster of Paris is obtained by gentle calcination of a crystalline limestone called *gypsum*, which is classified as a *hydrated sulphate of lime*, its constituents being water, salts of sulphuric acid, and lime. Extensive deposits of the stone exist in the environs of Paris, in France, from which fact the trade name is derived. The chief value of this plaster is that paste made from it rapidly sets and within a few hours acquires its full strength. It is very soluble in water, which renders it unfit for external use, but it is invaluable for cornice moldings and enrichments, and is also used in several plastic mixtures. Its volume expands in setting, and on this account it is a good material for filling chinks and holes in repair work. Plaster of Paris is much used for making casts, etc., which are generally molded hollow, owing to its liability of cracking when formed into pieces of any considerable thickness. When plaster of Paris is mixed with lime mortar, in which case it is said to be *gauged*, the setting is considerably hastened.

PLASTERERS' TOOLS.

222. The implements used by the plasterer are simple and inexpensive; the principal ones are shown in Fig. 103.

At (*a*) is shown the ordinary **screen** used for separating the coarser particles of sand and gravel from the finer ones. At (*b*) is shown a screen through which the slaked lime is passed to free it from gritty or unslaked particles. For very fine division, small wire and hair sieves are sometimes employed.

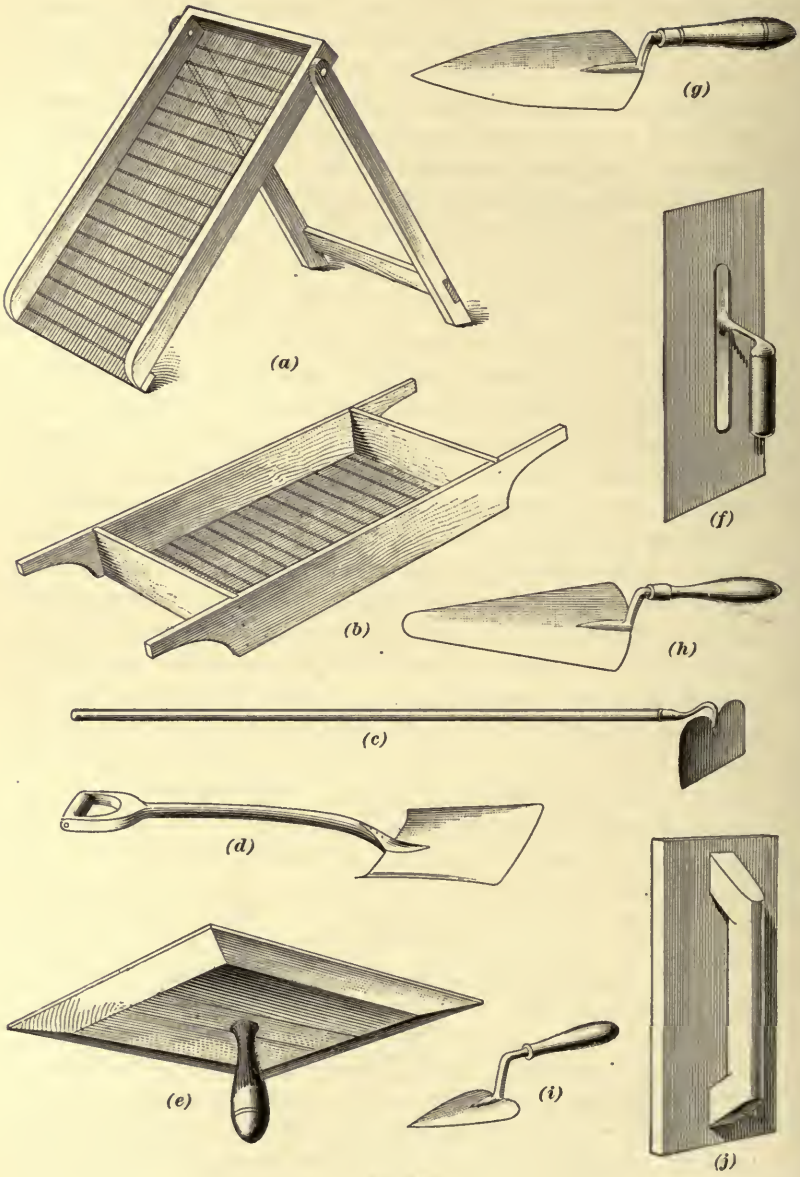


FIG. 103.

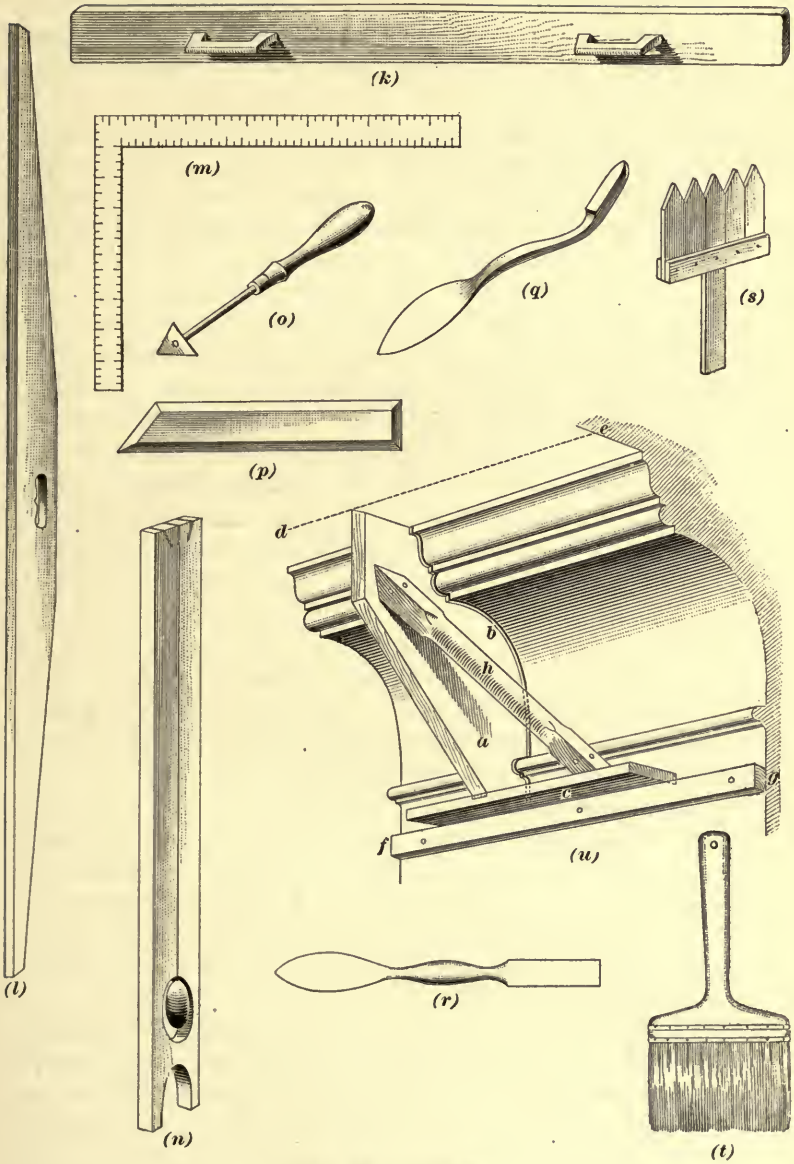


FIG. 103. (*Continued.*)

The **mixing box** is a platform of rough boards battened on the bottom and having sides 10 or 12 inches high, making a water-tight box, in which the lime is slaked and the materials mixed.

The **hoe** and **shovel,** shown at (*c*) and (*d*), are used in mixing the materials, etc.

The **hawk** (*e*) is a piece of board about 10 inches square, provided with a short handle. It is used to hold small quantities of prepared mortar, or *stuff*, ready for application by the trowel.

The ordinary laying **trowel,** shown as (*f*), is used for applying the plaster to the walls. It is a thin plate of polished steel, about 10 inches long and $4\frac{1}{2}$ inches wide, having a wooden handle. Various other forms of trowel, for gauging, pointing, etc., varying in length from 3 to 7 inches, are shown at (*g*), (*h*), and (*i*).

Floats are used for smoothing, or *floating*, the surface of the second coat. At (*j*) is shown the hand float, which is merely a piece of board with a handle on the back. It is usually made of pine, but for very fine work a cork face is sometimes used for producing the finished surface. For rough finish, the face of the float is often covered with carpet, etc. The two-handled float, called the *derby*, is shown at (*k*); this is a straightedged piece of wood, usually from 3 to 6 feet long, and is used for floating larger surfaces than can be readily worked with the hand float.

The **straightedge,** shown at (*l*), is a long piece of smooth board, having its under edge planed straight and true. It is used to test the walls and ceilings, in order to obtain plane surfaces.

The **square,** shown at (*m*), is used for testing the trueness of the angles.

The **plumb,** shown at (*n*), is used to determine the perpendicularity of the surfaces by applying one of its straight sides to the surface; if the plumb line, hanging freely, lies along a shallow groove cut in the face, parallel to the sides, the edges are plumb.

Jointing and **mitering tools,** shown at (*o*), (*p*), (*q*), and

(*r*), are used for picking out and finishing angles and miters in moldings, etc.

The **comb,** shown at (*s*), is used for scratching the surface of the first and second coats of plaster, to form a good key for the ensuing coat. It consists merely of pieces of lath, having one end sharpened, and nailed together as shown.

Brushes of various kinds are used by the plasterer. That shown at (*t*) is used for dampening the surface of the plaster, while it is being worked smooth.

Molds of various kinds are used for forming cornices, etc., and are made of wood or sheet metal cut to the required outline. At (*u*) is shown one form of mold, consisting of a board *a*, to the beveled inner edge of which is attached a thin zinc or steel plate, cut to the outline of the cornice as at *b*. The strip *c* and handle *h* brace *a* firmly and keep it square with the wall; *f g* represents a guide strip on which *c* slides, and *d e* a line drawn on the ceiling, flush with the outer edge of *a*, which is always kept along the line. Another form of mold is shown at *a*, Fig. 106.

PROPORTIONS OF MATERIALS.

223. The quantity of thoroughly slaked lime paste that a barrel of ordinary lump lime will yield varies from about 2.6 to 2.75 barrels. The voids in sharp and clean sand are about $\frac{1}{3}$ of its bulk. Probably the best plastering mortar is obtained by using sufficient lime paste to fill the voids in the sand $1\frac{1}{2}$ times; that is, the lime paste should be $\frac{1}{3}+\frac{1}{6}=\frac{1}{2}$ the volume of the sand, or 1 part of lime paste to 2 of sand. Measured in barrels, the lime (unslaked) and sand should be in the ratio of 1 to about $5\frac{1}{2}$. If lime is sold by weight, the same result will be had by using $2\frac{1}{2}$ barrels of sand to 100 pounds of dry lime. For 100 square yards of plastering, laid $\frac{3}{8}$ inch thick, it will require, at the above proportions, about $2\frac{1}{2}$ barrels of lime and 14 barrels of sand. For the best class of work, the quantity of hair used should be $1\frac{1}{2}$ bushels to 1 barrel of lime for the first, or scratch, coat, and $\frac{1}{2}$ bushel to 1 barrel for the second, or brown, coat. Generally, however,

plastering mortar contains less lime and hair than above given, although these proportions are not too much for first-class work.

It is a difficult matter to regulate the proportion and uniform mixing of common plaster, unless the operations are constantly watched. The ordinary method of mixing is to add as much sand to the slaked lime as the mixer thinks it will stand, and it is hard for the architect to determine whether or not there is too much sand; but considerable experience will enable one to judge the quality of the mortar by its appearance, or by trying it with a trowel when ready for use.

224. For scratch and brown coat on wood lath, with $\frac{3}{4}$-inch grounds, the following quantities are generally allowed for 100 square yards: 1,400 to 1,500 laths; 10 pounds 3-penny lathing nails; $2\frac{1}{2}$ barrels, or 500 pounds, of lime; 45 cubic feet, or 15 barrels, of sand; and 4 bushels of hair. For the best quality of white coat, the estimate is 90 pounds of lime to 50 pounds of plaster of Paris, and 50 pounds of marble dust. The same proportions can be used for large or small quantities.

MIXING PLASTERING MORTAR.

225. Hand Mixing.—The great bulk of plastering mortar, outside of a few large cities, is mixed by hand, and, for the best results, requires very close regulation of materials and careful manipulation. The mixing should be performed as much as possible outside the building to be plastered, so as not to make the interior damp from the steam of slaking lime. When mortar is mixed in cold weather, it should be done under shelter, and in no case should frozen mortar be used.

A good quality of lime having been selected, it is slaked with clean water in a tight box, and allowed to stand for at least 24 hours—a week is better—to allow all the particles to be acted on. If there is any residue after slaking, the lime paste should be run through a fine wire screen into another

box. This paste forms the base from which the various coats are made by addition of the other materials; the mixtures are generally classified as *coarse stuff*, *fine stuff*, *plasterer's putty*, *gauged stuff*, and *stucco*.

226. **Coarse stuff** is used for the first, or scratch, coat, and is made by mixing with the slaked lime, reduced to a thin, cream-like paste, the proper quantities of sand and well beaten-up hair. (The sand is usually added last, but some authorities claim that better and tougher mortar is made by adding the sand soon after slaking.) On government work, the specifications require that the hair be not mixed with the lime paste until the plastering is to be applied. The materials are thoroughly incorporated by a hoe, and piled in a heap for a week. The mortar is then mixed with sufficient water to give it the proper consistency. Only a small batch should be wet at a time, and should be laid at once on the lathing.

The common method is to mix the hair and sand with the lime as soon as it is slaked, and then throw the mortar into a pile, the entire operation not taking more than a few hours. This is a very poor way, as the lime will not slake thoroughly in such a short period, while the hot lime and steam will char the hair, so as to materially affect the strength of the plaster.

227. **Fine stuff** is the pure lime which has been slaked to a paste in a trough, by the addition of a small quantity of water, after which it is further diluted by water until it is as thin as cream. The substance is then allowed to settle; when the excess of water appears clean, the lime held in suspension having subsided, it is drained off, and the moisture in the mass is allowed to evaporate until the stuff has become sufficiently stiff for use. When desired, a small quantity of white hair is added to it.

Plasterer's putty is practically fine stuff, but the creamy fluid having been strained through a fine sieve, the paste has been rendered much more velvety. It is always used without hair.

Gauged stuff consists of about $\frac{3}{4}$ of the foregoing putty

and about $\frac{1}{4}$ of plaster of Paris. The latter article causes the mixture to set quickly, and the composition must be immediately used, not more than can be applied in 20 or 30 minutes being prepared. An excess of plaster in the mixture will cause the coat to crack. Gauged stuff is used as a finishing coat for walls and ceilings, and also for running cornices; for the latter work, equal portions of putty and plaster are used.

Stucco for interior work consists of $\frac{2}{3}$ fine stuff and $\frac{1}{3}$ sand; it is used as a finishing coat, the mixture being "whipped," and reduced, by the addition of water, to a thin paste.

228. Machine Mixing.—The advantages of machine-mixed mortar are that sufficient time is given for the lime to thoroughly slake, the hair and sand are added just before delivery, and the mixing performed much more uniformly than when done by hand. In brief, the process is as follows: The fresh lime is placed in revolving pans, with enough water added to slake the lime slowly. When this process is completed, the lime and water are run through screens and pumped into tanks, and allowed to remain about three weeks to finish the slaking. When mortar is to be made, the paste is run into the mixing pans, where the hair and sand are added and the mass is thoroughly stirred until it is entirely homogeneous.

APPLYING THE PLASTER.

229. Preliminary Examination.—Although the carpenter's specifications require that all surfaces be properly prepared for lath and plaster, and that suitable plaster grounds, such as shown at *e*, Fig. 104, be affixed to the masonry and framework for the future attachment of the finished joiner work, it is well for the plasterer to test the alinement of the walls and ceilings, or he may find that considerable "building-up" is necessary when he comes to apply the second, or floated, coat. Where this is necessary, the lathing should be stripped off, and the surfaces brought to a plane by the use of furring strips.

In the case of *dished*, or concave, surfaces on stone or

brick walls, the deficiency should be made good with cement mortar before the first coat of plaster is applied; this course will insure a more durable wall, as there is little value in a mass of lime mortar unless it is applied in thin layers and thoroughly compacted.

Particular attention should be given to the spacing of the lathing; although a simple matter in theory, it will be found

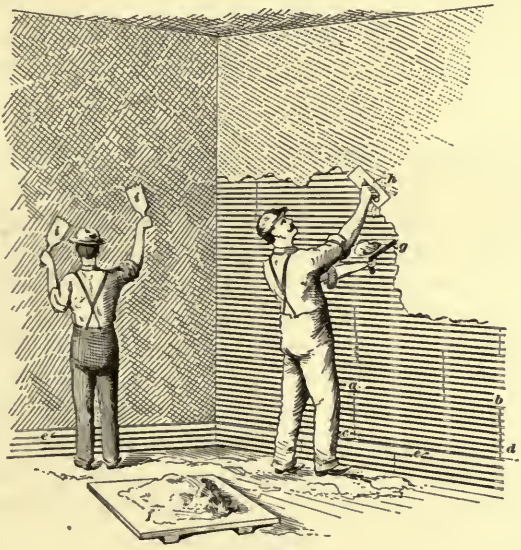


FIG. 104.

that in practice, unless much care has been taken in spacing the strips, that many narrow, insignificant slivers have been used for closers; these should be discarded and the panel stripped and relathed, otherwise much of the strength of the wall is lost.

For three-coat work, the grade in general demand, the plaster grounds on brick or stone walls, that are to be coated on the solid wall, should be $\frac{5}{8}$ inch in thickness, and those for lathed surfaces $\frac{7}{8}$ inch. At no point should the surface of the solid wall or that of the lathing approach the face of the grounds nearer than the regulation thickness for the plaster, which will be about $\frac{5}{8}$ inch. On stone or brick walls, the face of the masonry is more or less irregular, and

grounds less than $\frac{5}{8}$ inch in thickness are of little value for attachment of the finished woodwork.

230. Names of Coats.—Plaster is usually applied in three coats, although in some localities two is the customary number, the first coat being straightened and smoothed carefully to receive the finishing coat. This, however, is done in the cheaper kinds of plastering only. The first layer applied is called the *scratch* coat; the second, the *brown*, or *floated*, coat; and the third, the *skim*, *white*, or *finishing* coat. On brickwork and stonework, and also on terra-cotta partitions, etc., the scratch coat is usually omitted.

231. Scratch Coat.—The method of applying this coat is illustrated in Fig. 104. The coarse stuff is taken in batches from the *souring pile*, tempered with clean water to the proper degree of firmness, shoveled into hods, carried to the rooms and deposited on the mortar boards, as shown at *f*, ready for application by the plasterers. A quantity of mortar is placed on the wood hand board, or hawk, *g*, by means of the trowel *h*; slices of the mortar are then cut from the hawk and spread firmly and evenly over the surface of the lathing or naked wall surface, as the case may be. The mortar should have a dough-like consistency, should be tough and hold well together, and should be soft enough to be readily pressed in between the laths, so that it will bulge out behind and form the clinch, or key. The thickness of the layer should be a full $\frac{1}{4}$ inch, so that when set it will furnish a rigid surface to work over; in cheap work, it is often only a skim coat, and it is not unusual to see the rough-sawn grain of the lath protruding through its thickness. After the coat has somewhat hardened—which requires from 2 to 4 days after application—it is scratched over diagonally by wooden comb-like blades *i*; from this fact the first layer is often called the *scratch coat*. The scratches, or grooves, thus formed in the mortar fulfil the same function as the spaces between the lath—to allow a good key for the subsequent layers. The first coat should be nearly dry before putting on the next; if too dry, the surface should be

slightly dampened with a sprinkler or brush, on applying the second coat.

If the walls are partly masonry and partly wood, the first coat is only applied to the lathing—unless the stone or brick walls are furred and lathed also. When the scratch coat is dry, the second coat is spread over this and the masonry. If plastering is applied directly to brick or stone, the joints in the latter should be raked out, so as to form a better clinch for the mortar, and the walls should be free from dust, and be slightly dampened before putting on the mortar.

232. Brown Coat.—The second coat, consisting of fine stuff, to which a little hair is sometimes added, is applied from $\frac{1}{4}$ to $\frac{3}{8}$ inch thick, when the scratch coat has become sufficiently firm to resist pressure. The second layer is frequently called the *floated* coat, because its surface is worked by means of board-shaped trowels, called *floats;* it is also known as the *straightening* coat, since, by its application, all the wall surfaces are straightened and made true. On walls, if the grounds are set true and the surfaces are not too large, the plastering can usually be brought to a true plane without much difficulty. On the ceilings, however, there is nothing to guide the plasterer, and in many cases, if great care is not taken, the ceilings have a rolling surface, as may be seen at the edges.

In order to get perfectly level walls and ceilings, especially in cases where the grounds are insufficient, resort is had to what is known as *screeding*. *Screeds* are plaster bands, 5 or 6 inches in width, formed on the surface to be floated. The surfaces adjacent to the angles are carefully plumbed up from the plaster grounds *e*, Fig. 105, but kept about $\frac{1}{8}$ inch back from the face, to allow for the finishing coat, and vertical screeds *f* are formed by means of the straightedge *g*. Similar screeds *h* are formed along the ceiling angles; these screeds are made straight, and coincide with those at the opposite angles. Intermediate horizontal or vertical screeds, as *i* and *j*, are then formed between the screeds adjacent to the ceiling and the plaster grounds, as preferred by the plasterer; these are usually placed from 4 to 8 feet apart, and are gauged

to line by means of the straightedge. The screeds thus form a system of framing which has been reduced to a true plane; the panels may then be filled in flush, in line with the screeds,

FIG. 105.

and firmly rubbed down with the two-handled, or derby, float *k*. The surface is then worked over with a wood hand float, the coat being firmly compacted, by incessant rubbing; when the coat becomes dry, during the process, it is moistened with water, applied by a wide brush. A close, firm layer can be obtained only by the thorough, laborious operation of pressing and rubbing the particles of the mortar together; and herein lies the secret of strong, durable work—plenty of "elbow grease." In order to form a rough base for the subsequent coat, the surface is scratched over with a broom. The ceiling surfaces are treated in a similar manner, and the screeds are carefully leveled so as to secure true and level planes.

The space between the plaster grounds and the floor is usually finished with a scratch and a brown coat of plaster, so as to prevent air-currents entering the room through the spaces between the furring strips; in cheap work this filling is omitted, the spaces being covered by the finished wood base.

233. Very often the brown coat is put on immediately after the scratch coat, without allowing time for the latter to dry; this is known as *green* work. In such a case, the first coat is made very rich, while the brown coat contains a large proportion of sand, and is worked into the first coat so as to really form but one. While it saves time, this practice cannot be commended; it is much better to allow the scratch coat to dry before the brown coat is put on, although more labor and lime are thus required. Another objection to green work is that the excess of moisture causes the laths to swell badly, which, in drying, shrink and produce cracks in the plastering. Nearly all lime plastering is green work, unless otherwise specified.

234. **Cornices** are usually molded before the finishing coat is put on; the operation of making them is about as

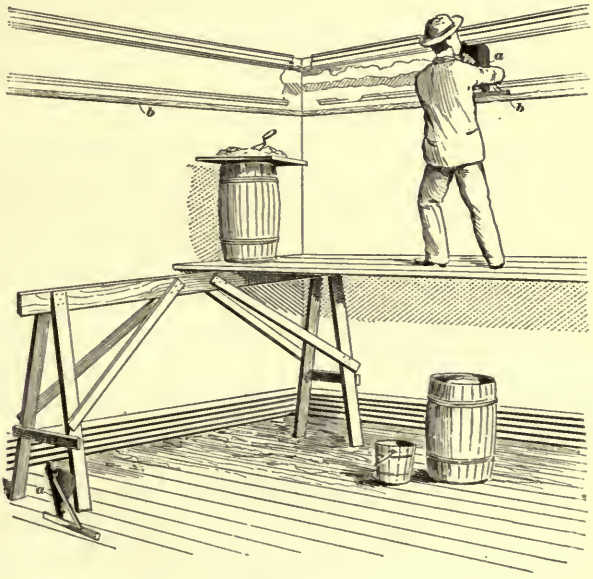


FIG. 106.

follows: Longitudinal strips *b*, *b* are first attached to the wall, as at *b*, Fig. 106, or *f g*, Fig. 103 (*u*), on which the mold

guide runs. Sometimes a strip is also attached to the ceiling, but more often the ceiling guide is merely a line, as *d e*, Fig. 103 (*u*). The coarse stuff is made to conform to the approximate profile with a *muffled* mold, that is, by forming a layer of plaster of Paris along the edge of the mold, about $\frac{1}{8}$ inch in thickness, or an extended profile can be cut out of zinc and attached, temporarily, to the correct mold. The mold is placed in position and pushed along the angle of the wall, as indicated in Fig. 106. When the coarse stuff has been correctly profiled, the surface is coated with gauged stuff and carefully worked over with the correct mold, until an exact and perfect finish is obtained. The internal and external angles cannot be finished by means of the molds, but require to be carefully molded and mitered by hand, using jointing tools, such as shown in Fig. 103. Some plasterers prefer to push the mold with the left hand, instead of with the right, as shown in the figure, so that they can handle the trowel with the right hand, when applying the stuff, to make up any deficiency; therefore the molds require to be made to suit the direction in which they are intended to be driven.

235. Sometimes the clinch, or key, is reinforced and the plaster held more firmly in place by the use of projecting spikes or large nails, driven into the wall or ceiling before the mortar is applied, as in Fig. 107, in which *a* shows the mortar; *b*, the laths; *c*, the spikes; and *d*, the finished surface.

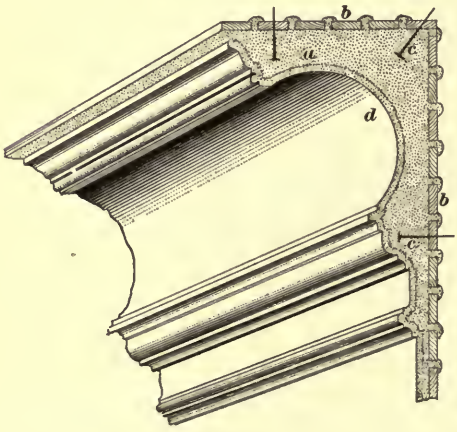


FIG. 107.

236. When the cornice projects considerably, the angle must be blocked and lathed, to reduce the quantity of plaster required, as there should be no thickness

of plaster much over 3 inches. This method is represented in Fig. 108, in which *a* shows one of the blocks which are nailed to the floor joists; *b*, the lathing; *c*, the cornice; *d*, a dentil course; and *e*, an egg-and-dart molding. If the cornice is to be ornamented, as at *d* and *e*, recesses are left in the plastering, to receive the pieces to be inserted, which are formed separately and then stuck in place by liquid plaster.

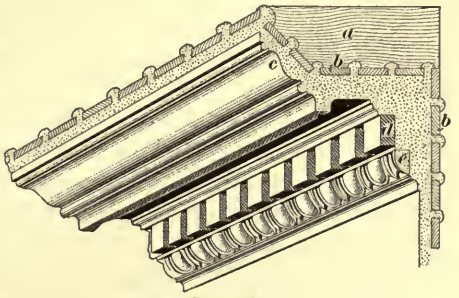


FIG. 108.

When there is much ornament, it is cheaper to cast the cornice of plaster of Paris in sections 2 feet or more long; these may be attached to the wall by thin plaster. Careful work is required to make the molded pieces come together, or match properly.

237. Centerpieces, consisting only of plain circular moldings, are formed in the same way as cornices, except that the mold, or templet, is so fastened as to swing around the center of the ornament.

When decorated centerpieces are used, they are usually cast in a mold and stuck on the ceilings with liquid plaster of Paris. Nearly all kinds of ornamental plastering, such as paneled ceilings, bas-reliefs, imitations of foliage, etc., may be easily cast of plaster of Paris, and serve the purpose as well as more costly decorations.

238. Finishing Coat.—Sometimes this coat is omitted, in cheap work, when the walls are to be papered, the brown coat being smoothed as well as possible. This method is not a good one, as the rough plaster is likely to mar the smoothness of the paper.

There are several kinds of finishing coats, such as *troweled stucco*, *rough sand finish*, *hard-finish white coat*, etc.

In all cases the material is applied to the wall in the form of a stiff paste, by means of the steel trowel *a*, as shown in Fig. 109, and is spread uniformly over the surface to a thickness of about $\frac{1}{8}$ inch.

The **troweled stucco,** consisting of fine stuff and very fine white sand, to which a little white hair may be added, is thoroughly polished to a glazed finish with the trowel *a'*, the surface being kept moist by water applied with the brush *b*. This is frequently called the *skim* coat.

Rough sand finish may be produced on the stucco by covering the hand float with a piece of carpet or felt, which

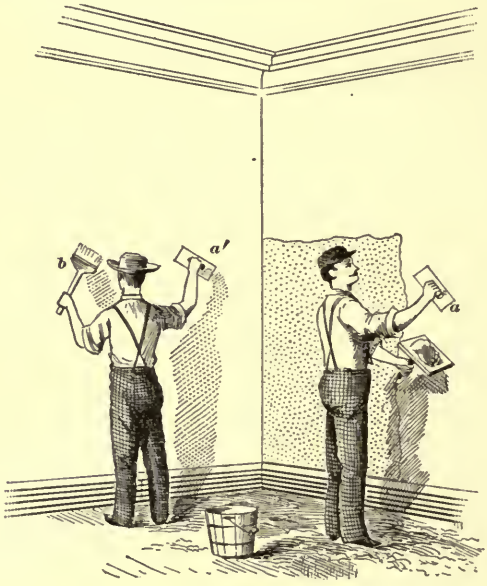


FIG. 109.

will cause the sand to rise and present the characteristic sandpaper surface. It may also be made by using more and coarser sand with the lime putty.

Hard-finished white coat consists of gauged stuff, smoothed and polished with the steel trowel; as this material sets rapidly, care must be taken to observe that the

second coat is well dried; otherwise, the unequal shrinkage will cause hair cracks to occur all over the finishing coat. Marble dust is frequently mixed with the gauged stuff to give greater hardness and a surface susceptible of higher polish, about equal quantities of marble dust and plaster of Paris being used.

HARD WALL PLASTERS.

239. While, by the use of the best materials and proper care in preparing and applying them, a good wall may be obtained with lime plaster, yet there are so many uncertainties about it that numerous substitutes have been brought into use, which have proved valuable and efficient. These are known under the general name of *hard wall plasters*, and may be divided into two classes: *natural cement plasters*, and *chemical*, or *patented*, *plasters*.

240. **Natural plasters,** such as *Agatite*, *Royal*, *Acme*, etc., are made from earths—found in Kansas and other states—which resemble plastic clay in appearance, and in chemical nature are similar to gypsum, from which plaster of Paris is made. They are produced by heating the natural earth to a high degree, which expels all the moisture. When mixed with water, they set like hydraulic cement, but much more slowly, thus allowing ample time for applying the mortar. These plasters have great strength and adhesive power; the full strength, however, is not attained till from one to two months after application. A sample of Agatite several weeks old showed a breaking strength of 370 pounds per square inch, a strength exceeding that of many cement mortars of the same age.

They work smoothly under the trowel, and adhere very firmly to wood, stone, or brick, without the use of fiber or any other binding material, although such is generally used when the plaster is applied to lathing. Most of these cement plasters must be mixed with sand before using, but are

prepared with and without fiber; the former kind is used for the scratch coat on lathing, and the other for the brown coat, or for the first coat on brick or tile. As they are grayish in color, the finishing coat is made of lime and plaster of Paris, which is put on as before described.

In some respects these plasters are superior to natural cement, and have been substituted for it with considerable advantage in setting fireproof tiling, etc.

241. Chemical, or patent, plasters include *Adamant*, *Windsor Cement*, *Rock Wall*, *Granite*, *Rockite*, and others. While the exact composition of these plasters is unknown to the public, they appear to consist of plaster of Paris, with some material added to lessen the natural rapidity of setting of that substance, so that sufficient time will be had to apply the plaster. As far as known, the only difference in these plasters is in the materials used to render them slow setting.

Most patent plasters are sold containing sand and fiber, and only require mixing with water to be ready for use. Numerous grades are made for the different coats and application to various surfaces. The plaster known as *Adamant* was the forerunner of all hard plasters, and is probably more extensively used than any other; but, while the oldest are likely to be the most reliable, all of these plasters will doubtless give good results if properly applied.

242. Keene's Cement.—When it is necessary to give walls, ceilings, etc. a hard and highly polished surface, a prepared plaster known as *Keene's cement* is generally used as a finishing coat. Strictly speaking, this is not a cement, but is made of plaster of Paris, soaked in a solution of alum and then recalcined. Applied to the walls, this material becomes very hard and takes a high polish, so that surfaces finished with it may be washed without injury. Its hardness also makes it very satisfactory to use for finishing the lower portions of walls where the surface is liable to injury by contact with furniture, etc.

243. Application of Hard Plasters.—The method of applying these plasters differs in no essential respect from that described as green work in lime plastering. As they are more like cement than lime, the hard plasters set instead of drying. The material should be mixed fresh every hour or two, only enough water being used to give them the proper consistency; no plaster should be remixed that has partially set. When the plaster is to be applied to stone, brick, or tile, the surfaces should be sprinkled before putting on the coat. Wood lathing should also be well moistened, so that they will swell before, and not after, the plaster has begun to set. The makers of hard plasters recommend that the laths be spaced $\frac{1}{4}$ inch apart and that $\frac{3}{4}$-inch grounds be used. A better wall, however, will be obtained by using $\frac{7}{8}$-inch grounds and $\frac{3}{8}$-inch key. All these plasters, except Adamant, can be finished with a third coat of lime, putty, and sand, which should not be applied until the second coat is thoroughly dry.

When not used properly, hard plasters are inferior to lime plaster, so that the manufacturers' directions for applying them should be carefully followed.

244. Advantages of Hard Plasters.—Hard plasters have many points of superiority over lime plaster, which more than balance their extra cost, and which will, in time, probably result in their almost exclusive use. Being machine-mixed, the plaster made from them is uniform in quality and strength, and has unvarying proportions of the constituents, while two batches of lime plaster may differ a great deal in this respect. They are also much harder and more tenacious, and resist fire and water better than lime, and the small quantity of water used in mixing enables them to dry much more rapidly. They are not injured by frost after they have begun to set, but should be protected from it for the first 36 hours after being put on the walls. Heat and moisture are not readily transmitted by hard plasters, and, being more dense than lime plaster, they do not absorb noxious gases or permit the entrance of disease germs.

PLASTER ORNAMENTS AND SCAGLIOLA.

245. **Plaster ornaments** are now much less used than formerly. They are usually made of plaster of Paris and lime, but for cast work, only the former is used.

A light and strong material, used to some extent for ornamental work, is made by applying a thin layer of plaster of Paris to pieces of stretched canvas, forming a kind of board. If casts are to be made, the plaster is poured into the molds, and, while it is still soft, the canvas backing is pressed slightly into it.

Another material, known as *carton pierre* and by various other names, is also much used for ornamental work. It is composed of whiting (ground chalk), paper pulp, hemp fiber, etc. mixed with glue, and pressed into molds, backed with strong paper, and dried. Ornaments made of this substance are much tougher and lighter than if cast in plaster of Paris, and are considerably used for interior decorations, and also for outside work; for the latter use they should be painted.

246. **Scagliola** is a material applied to columns, walls, etc., to imitate marble. The first, or ground, coat consists of lime mortar having a large proportion of hair mixed with it; this is applied in the usual way and allowed to become thoroughly dry. Another coat is then applied, composed of Keene's cement, or plaster of Paris mixed with glue, or gelatine, to make it more dense and compact, and to retard the setting. Various coloring matters are also added, to produce the required effect. The second coat is sometimes put on with a brush, a great many applications being necessary to properly blend the colors. To impart to the work the requisite polish, similar to marble, the workman rubs the surface, when it is hard, with pumice stone; then polishes it successively with tripoli, pulverized charcoal, and a piece of soft cloth, and finishes with oil. When well made and polished, scagliola can hardly be distinguished from marble. It is unsuitable for exterior decoration.

but for interior work is nearly as durable as good stone, and in Europe there are columns made of it which are hundreds of years old.

STUCCO.

247. The term **stucco** was first used by the early Italian artificers to define a superior grade of plaster compounded by them; and their skilful manipulation of the material has never been excelled. From the fact that the appearance of dignity and stateliness could be acquired by its use, on an otherwise mean and poverty-stricken erection, at a very low price, it was for many centuries most extensively used. Many of the so called stone and marble palaces will be found on examination to be but brick shells, coated or veneered with stucco, so well treated and handled as to present a very superior surface, scarcely discernible from the material that it is made to imitate. At the present time, stucco is used only to a limited extent, and only for a cheap class of structures.

To secure the best results in stucco work, a good cement mortar is requisite, as lime mortar, which was formerly used, does not prove very durable. For use on brickwork, the plaster should be made of Portland cement and clean, sharp sand, mixed in the proportion of 1 part of cement to 3 parts of sand, with sufficient water to make a stiff paste. Before adding the water, the mortar joints in the brickwork should be raked out, so as to form a good clinch for the covering, and the surface of the wall should be well dampened, to prevent the brick from too quickly absorbing the water in the mortar. Resort is sometimes had to screeding, to make the surface true and uniform. When the mortar is put on in more than one layer, the previously laid coat should not be allowed to dry before the next one is applied, else the coats will not adhere well, and will probably scale off. Before the finishing coat has hardened, it may be marked with lines to imitate the joints in ashlar. The mortar may be colored to represent stone by use of mineral colors, such as

Venetian red or the ochers; while, if a light color is desired, it may be obtained by mixing a small quantity of lime with the cement.

248. Rough cast is a kind of coarse plastering considerably used in Canada and other cold climates, as a substitute for siding and shingles; it costs less, is more durable and much warmer than wood, and resists fire to a considerable extent. If a frame building is to be covered, it should first be stiffened by having the partitions built and the outside sheathing put on. On the latter are then nailed laths, laid diagonally and about $1\frac{1}{2}$ inches apart, breaking joint about every 18 inches. Over this course is laid another, the laths sloping in the opposite direction, with similar spacing and broken joints. This thickness of lathing should be put on with great care, to insure the permanence of the work; if wire or expanded metal lathing is used, there will be considerable gain in strength and fireproof qualities. The scratch coat should be made of rich lime mortar having a large proportion of hair, and should be mixed about four days before it is applied. This coat should be thoroughly laid on and well pressed between the laths, to form a good clinch, and the surface should be well scratched to form a key for the second coat. It must be allowed to dry thoroughly, but its surface should be sprinkled before applying the second coat, which has the same composition as the first. This should be kept moist and soft until the finishing coat is put on. The latter is called the *dash*, and is made of clean, fine gravel and lime stirred up with water until the mass has a semifluid consistency; various coloring matters may be added, if required. A black mortar may be obtained by mixing 5 pounds of lampblack with the dash; a buff, by using a like weight of copperas. The dash is then thrown upon the plastered walls with a wooden float about 5 or 6 inches square; before it dries, it is gone over with a brush dipped in the liquid, to give the face a uniform appearance.

For 100 square yards, applied as above described, there will be needed 1,800 laths, 16 pounds of $1\frac{1}{4}$-inch lath nails,

12 bushels lime, $1\frac{1}{2}$ barrels hair, $1\frac{3}{4}$ cubic yards of sand, and $\frac{3}{4}$ cubic yard washed gravel. For the dash, a quarter barrel of lime putty should be mixed with every barrel of washed gravel.

249. Staff was first brought into extensive use, in this country, in the construction of the World's Fair buildings in Chicago in 1891–93, although it has been used for a long period in Europe. As used in Chicago, it is made about as follows: The ingredients are plaster of Paris, water, and hemp fiber, the latter being used to bind and strengthen the cast. A suitable mold having been made, the hemp is cut into pieces about 6 or 8 inches long, bunched loosely, dipped in the liquid, and placed in the mold in layers until the mold is full, each handful being interwoven with those previously laid, and pressed in so that the cast will be compact and uniform throughout. When the mold is filled, the surface is smoothed over by hand, and the cast is removed when set. About 36 hours are necessary for thorough drying, in warm weather; in winter, more time is required, and the cast should not be subjected to frost before it is dry.

Staff may be nailed directly to the rough boarding of a wooden building; if it is to be applied to a new brick structure, furring strips should be inserted in the brickwork.

This material, while cheap and satisfactory for temporary structures, does not seem well adapted for permanent buildings, as it deteriorates in course of time in the Northern states, owing to the rapid changes of temperature. Where the temperature is more uniform, staff has proved to be a very durable material.

WHITEWASHING.

250. Whitewashing being often included in the plasterer's specifications, a brief mention of it is desirable. Common whitewash is made by slaking fresh lime, adding enough water to make a thin paste, and is applied to walls,

etc. with a brush. Whitewash will adhere best to rough and porous surfaces. For good work, two coats should be put on. By using 20 pounds of sulphate of zinc and 1 pound of salt to each half bushel of lime, the whitewash will be rendered much harder, and will be prevented from cracking. Its durability, especially for outside work, may be increased by mixing a pint of linseed oil with each 2 gallons of whitewash.

Whitewash is a very useful agent in preventing decay of wood, and is valuable from a sanitary point of view, in wood, stone, or brick buildings.

FIREPROOF LATHING AND PLASTERING.

251. It is evident that, if buildings are to be fireproof, as little wood as possible should enter into their construction; hence, only expanded metal or wire lath should be used to hold the plaster, unless the floors and partitions are of tile, in which case very little lathing is required. The plaster should be either one of the hard kinds or machine-mixed mortar, preferably the first. Where a hard plaster is to be applied to lathing, the latter should have a close mesh, and should be either galvanized or painted.

252. Girder Protection. — Cornices to protect and

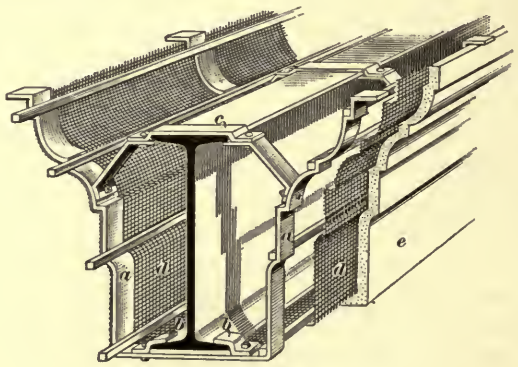


FIG. 110.

conceal girders are often formed by constructing a frame of light iron strips and covering it with wire lath, to which the

plastering is applied. This method of casing a girder is represented in Fig. 110, which shows a stiff framework of light iron bars *a*, bent to form the desired outline, and attached to the girder by clamps *b* and *c*. To this frame is fastened the wire cloth *d*, upon which the plaster *e* is laid.

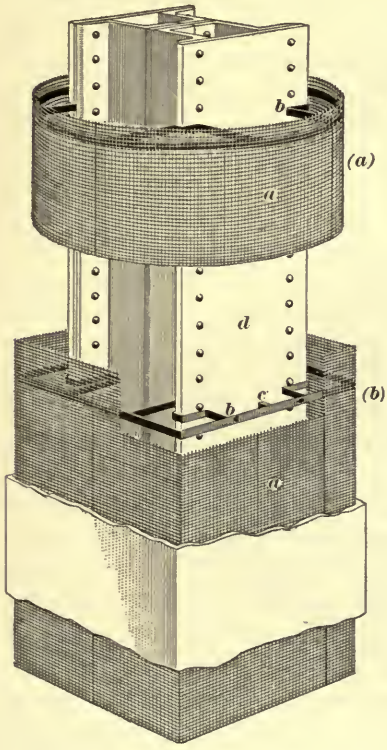


FIG. 111.

253. Column Protection.—Fig. 111 shows the method of casing a column, using a similar framework, securely fastened to the column. At (*a*) and (*b*) are indicated the methods of forming round and square columns; the wire cloth *a* is wrapped around and fastened to light frames *b*, spaced at proper distances, and firmly clamped, as at *c*, to the column *d*.

254. Partitions.—Fig. 112 represents a method of constructing thin partitions, using very light T bars, or channels, and wire lathing to support the plaster. At *a* is shown one of the $\frac{3}{4}$-inch channels, which are spaced from 12 to 16 inches apart and firmly fastened to both floor and ceiling; at *b* is shown the wire cloth, stretched and laced to the channel studs; at *c*, the plastering, which should be the best kind of work, as upon it depends largely the stiffness of the partition; and at *d*, a $2'' \times 3''$ piece of wood, to which the baseboard *e* is nailed.

Another form of thin wire partition has a $\frac{1}{4}$-inch rod woven into the cloth at distances of about 8 inches. The lathing is tightly stretched over the studs, with the rods crossing

the latter at right angles, and well laced where they cross.

When moldings are required, strips of wood may be laced to the lathing at the proper height. The plaster when put

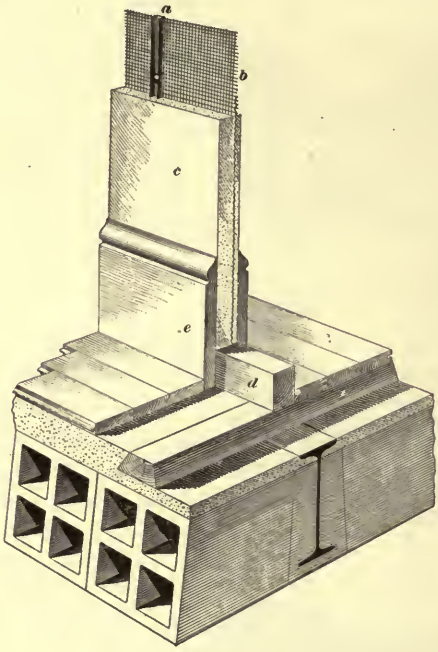


FIG. 112.

on holds the strips firmly in place, and the picture mold may be screwed to it. If a close-mesh lathing is used, the moldings may be fastened by screws directly to the wire cloth.

INSPECTION OF WORK.

255. Lathing.—Before the lathing is begun, the inspector should see that the furring and grounds are properly placed and are plumb and square; also, that the angles of chimneys and other projections are right angles. If the lathing is wood, he should see that the laths are free from bark

and loose knots, and that they are put on with proper spacing, well nailed, with no springy ends, and end joints broken at least every 18 inches. Over door and window openings, the laths should extend to the next stud on either side of the frame. As far as possible, the lathing should run the same way, as cracks are likely to appear in the plastering at the places where the direction of the laths is changed. The junction of brick and wooden walls, as well as lintels and unfurred timbers, should be covered with metal lath, as before mentioned.

256. Plastering.—If lime plaster is to be used, the inspector should see that the lime is fresh and without unburned lumps, and should allow none to be used that has begun to slake. The sand used should be sharp and free from earthy matter. The hair should not be added until the lime has become thoroughly slaked and cooled, and the mortar should be made at least a week before use. It is well to become acquainted with the appearance of good mortar, so as to be able to judge its quality.

Before beginning to plaster, the openings in the building should be closed up with boards or canvas. In winter, a building in which plastering is to be done must be heated; lime mortar, especially, is rendered worthless if frozen and thawed; hard plasters, also, should not be permitted to freeze. The inspector should see that the first coat is well clinched between the lath, and is thoroughly dry before the second coat is put on. If the scratch coat is to be laid on brick, the walls should be well wetted before applying the mortar. Special care should be taken with the brown coat, as the appearance of the finished work depends to a great extent upon good workmanship in applying this coat. Its surfaces should be plane, with straight and square angles and a level ceiling. If hard plasters are used, the directions furnished by the makers should be carefully followed, in regard to mixing sand, etc. (if not obtained already mixed). Plaster that has partially set before use should be rejected.

TABLE 5.

Description of Work.	Average Cost in Cents, per Square Yard.	
	New York.	St. Louis.
* Two-coat work on brick or tile	30 to 35	17 to 20
* Three-coat work on wood lath	35 to 40	20 to 25
* Three-coat work on stiffened wire lath ‡	70	55 to 60
* Three-coat work on expanded metal ‡	70	55 to 60
† Windsor cement or Adamant on brick or tile	40	
† Acme or Royal cement on brick or tile	40	22 to 25
† Windsor cement or Adamant on stiffened wire lath‡	75	
† Acme or Royal cement on stiffened wire lath‡	75	60
Cost of stiffened wire lath on wood joist, about	35	
Cost of expanded metal on wood joist, about	25	30
Cost of perforated metal lath on wood joist		25
Stucco cornices less than 12-inch girth, per lineal foot	20	20
When more than 12-inch girth, per square foot	24	20

* Lime mortar, the last coat white finish.

† Finished with lime putty and plaster.

‡ When applied on wood joists or furring. When applied over metal furrings, the cost is about 20 cents per yard more.

Enrichments cost from 8 cents up per lineal foot for each member.

MEASUREMENT AND COST.

257. Lathing is figured by the square yard, and is usually included with the plastering, although in rural districts the laths are often put on by the carpenter. Plain plastering, such as that on walls and ceilings, is always measured by the square yard. Provision should be made in the contract as regards deduction for openings, for, unless this is agreed on, the custom of the locality will govern. In some parts of the country one-half the area of openings is deducted, and elsewhere no allowance is made for openings, unless they are very large.

Where the work is difficult to put on, or where there are many angles, as in closets, the underside of stairs, etc., the price per yard is usually more than for broad, unbroken surfaces. This is also the case when staging is required, and when the surfaces are other than plane. Ornamental work, of course, costs much more than plain; cornices, moldings, etc. are usually measured by the lineal foot, with extra allowance for corners.

258. **Cost.**—The ordinary prices for wooden lathing and lime plastering on plain surfaces vary from 20 to 35 cents per square yard, according to the cost of materials, number of coats, character of work, and also with the locality; 25 cents for ordinary three-coat work with white finish is about the average price throughout the country. The hard plasters cost from 2 to 10 cents per square yard more than lime plaster. Metal lathing costs from 20 to 40 cents per square yard more than wooden laths. In Table 5 is given the average cost of plastering in the cities of New York and St. Louis.

FLOOR TILING.

259. The method of manufacturing tiles for floors and wainscots, etc. is similar to that described under "Terra Cotta," but as these uses of tiles are in the nature of finishing processes, analogous to plastering on walls, the subject is considered separately from terra cotta.

260. Tiles are used very extensively for flooring aisles and passages in churches, office buildings, the floors of waiting rooms in railway stations, and also for vestibules, bath-room floors, hearths, borders, and backs of fireplaces in dwellings. Very artistic effects may be produced by use of different colors and shapes; and for wainscots, by use of the great variety of plain and decorated tiles. Tiles are of every color, and are made as large as 6 inches square, but it is not recommended that pieces of this size be used for flooring, as they are likely to break or become loose, unless very carefully laid.

261. The art of laying mosaic floors was known to the Romans, by whom the component parts were termed **tesseræ,** from the word meaning *tesselated*, or checkered. These consisted of small pieces of hard material of various colors, bedded one by one in a layer of cement, each piece being leveled with the others; and on the completion of the work any irregularities were corrected by rubbing the whole to a plane surface.

The modern tile floor is composed of pieces cut by dies; the pieces are thus uniform in size, and fit closely together, having an almost imperceptible joint. As a guide in setting, a colored drawing of the intended design is usually made. The full-sized pattern is laid out on a perfectly level cement floor, upon which the tesseræ are placed, the workmen being guided in the arrangement of colors, etc. by the drawing. The pieces are afterwards joined together by a layer of cement applied to the upper surface, and in this way can be formed into slabs of convenient size, which, when hard, are ready for use, and can be easily laid, either as centerpieces, borders, or pavements.

262. Tiles may be laid directly on the concrete of any of the fireproof floors before described; but when the floor is framed with wooden beams, the foundation course is brick, set edgeways on short pieces of board, laid on strips nailed to the sides of the beams; but to save material the bricks

are sometimes laid flat. The average thickness of the tiles is $\frac{1}{2}$ inch, although they often run $\frac{5}{8}$ inch, so that the top of the brick should be $\frac{3}{4}$ inch below the finished floor. The top of the beams should stand in the same relation to the tile that they would to the top of a wooden floor, in order to avoid differences in level at the junction of the wooden and tile floors. In the case of a single wooden floor, the distance will be $\frac{7}{8}$ inch, and in a double floor, $1\frac{3}{4}$ inches.

After the brick are laid the brick surface should be swept clean, and well dampened. The tiles should also be soaked in water for some time before they are used. If this precaution is not taken, the brick or tile will absorb water from the thin layer of cement between them, making it powdery and useless. The best Portland cement, only, should be used, the American brands, when fresh, being equal to most of the English. The cement. should be mixed rather thin, without sand.

263. The pattern—when the tiles are laid with a centerpiece—should be commenced at the center, the position of which should be accurately ascertained by previous measurement. Straightedged strips of board should be put down as guides for each day's work, not only for regulating the lines of the pattern, but also for securing a uniform surface, which is done by first setting the strips carefully, and then laying the tiles by aid of a straightedge resting on the strips. Each tile is set on a bed of cement spread for it, and beaten down to the proper level by the wooden handle of a trowel. When a sufficient number of tiles has been laid, the joints may be grouted with liquid cement, which must, however, be immediately wiped off the surface of the tiles, since it is difficult to remove when dry.

If the cement used is good, the tiles cannot, after a few days, be removed without breaking, so that too much care cannot be exercised in placing them properly at first. When the pattern reaches the edges, it is usually necessary to cut many of the tiles. This can be done by soaking them well in water, and then scoring a line with a sharp chisel, where

the separation is to be made; by placing the chisel exactly on the line, a sharp blow will effect the separation. Wide chisels should be used, and the tiles must be well soaked, for unless this is done they are likely to fly into fragments.

After the floor is finished, it is covered with sawdust an inch or so deep, and planks are laid over the tile, to walk on. When there is a baseboard and wainscot, whether of wood or stone, it is then fitted down upon the tiling.

264. If marble tiling is used in place of terra-cotta tile, the laying should be done in the same way, on bricks set on edge. The marble tiling is considerably thicker than the clay tile, generally from $\frac{7}{8}$ to $1\frac{1}{4}$ inches, and the guide strips should be set accordingly. The under side of the marble is usually quite rough, and the laying is easier than that of clay tile. Mortar of cement, lime, and sand, made in equal parts, may be used.

CARPENTRY.

PROVINCE OF CARPENTRY.

1. The **art** of **carpentry** consists of the theoretical and practical knowledge necessary to properly execute all classes of structural work composed of wood.

2. The province of carpentry is a most extensive one, and the subject is generally qualified by prefixing a term denoting the class or character of the carpentry implied; thus, we have house carpentry, bridge carpentry, and ship carpentry. Wagon making, carriage making, car building, etc. also partake of the principles and practice of the same trade.

3. The instruction in this course will be limited to that of **house carpentry,** and it will include the essential features which define the anatomy of construction of which all classes of buildings are more or less composed, except those classified as *fireproof structures*, in which the members are made of iron or steel.

4. The carpenter is distinguished from the joiner in that his efforts are directed towards the formation and disposition of the "bones," or constituent parts, of the "skeleton" of the building, or to such parts as have reference to structure only. His operations all tend towards the stability and efficiency of the framework of the edifice, while those of the

joiner tend towards clothing or encompassing the framework with finished woodwork, so as to render the building more agreeable and habitable.

The joiner does not commence his labors until the framework has been completed; therefore, it will be seen that the strength and vitality of the building largely depends on the effective character of its carpentry; the work of the joiner may be entirely removed, and yet the structure would remain intact, so far as the anatomy of its form and arrangement would be concerned.

5. The art of carpentry comprises three divisions, each of which is incorporated in a successful structure, namely, *analytic*, *descriptive*, and *constructive*.

The first and second divisions are contained in the *theory*, while the third constitutes the *practice* of carpentry. The first includes the analysis of the forces which generate the stresses in the framework, which is demonstrated by the *laws of mechanics*, and the disposition of the material for efficient resistance, which is regulated by a knowledge of the *strength of materials*.

The second defines the lines and methods deduced by geometric rules for laying out the work; while the third comprises the manual operations of cutting, framing, arranging, and uniting the various timbers which constitute the structure.

TIMBER.

PROPERTIES OF TIMBER.

6. A general knowledge of the properties and kinds of timber, the laws of growth and development, the characteristics of good timber, its natural defects, its conversion into building material, its shrinkage during the process of drying, modes of drying, etc. should be possessed by the student, in order to enable him to intelligently judge of the value of the material which he handles, and to provide for its disposition

and arrangement so as to secure the most stable and permanent construction.

7. To suit the purposes of the carpenter and joiner, the tree should not be cut until it has reached the period of mature growth; soon after this growth is reached, the heart begins to decay, hence the necessity of cutting, or *felling*, as it is called, at the proper time. After felling, the trunk and the larger branches are cut into suitable lengths, in which condition it is classified as *timber*, but when cut up into planks, etc. it is generally called *lumber*.

8. There are three divisions of trees, each being classified in accordance with its respective mode of growth: (1) The **exogenous,** or outward growers, in which the stem increases by the formation of annual layers deposited around the *outside* of the preceding layer; such as oak, chestnut, pine, hemlock, etc. (2) The **endogenous,** or inward growers, in which the woody matter is formed on the *inside* of the stem, of which the palmetto tree is an example. (3) The **acrogenous,** or summit growers, in which the stem is produced by the lower stalks of the leaves growing together, such as tree ferns.

9. The first division, or the *exogenous* method of development, is the one that furnishes the timber for the woodworker. On examining the section of a young oak tree, such as shown in Fig. 1, which is a microscopic enlargement of a section of a stem of 3 years' growth, we find three well defined kinds of tissue forming it; the pith, the woody layers, and the bark. At the core, or heart, at *a*, is seen the *medulla*, or pith, composed of cellular tissue, a

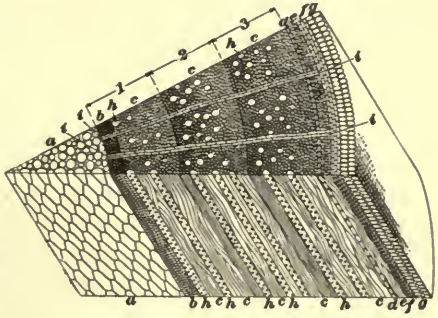


FIG. 1.

net-like fabric of cells, resembling a honeycomb; at *b*, the *medullary sheath* surrounds the pith and is composed of spiral vessels and fiber ducts for the conveyance of the sap; this constitutes the inner layer of the first year's growth; at *c* are the *wood cells*, or fiber tubes, composing the successive annual layers which are formed in a series of concentric rings; each annual layer is called a *zone*, or circular belt, as shown in Fig. 1, at *1*, *2*, and *3*.

10. Observe that there is a well defined line of separation between each pair of zones; about one-half of the width of the zone is occupied by bundles of fiber tubes containing large sap vessels *h*, *h*, whose walls are pitted and dotted as shown, while the remainder of the width is filled with fiber tubes of much closer texture. In ash, chestnut, and oak, the vessels *h*, *h* are easily observed.

The line of separation is caused by the suspension of the growth of the stem during the winter. When the tree is young, the tissue is open and spongy, and filled with various fluids, but in process of time, it becomes thickened and firm and the ducts close, the thickening of the tissue commencing with the first formed layer. For this reason the best timber is secured from mature trees, the fibers have become compact and firm, and when once well seasoned, are less sensitive to changes of temperature. Both young and second-growth timber are unfit for all purposes where strength, durability, and "staying" qualities are concerned, the last named quality being a most essential one to the carpenter and the joiner.

11. Much difference as to strength and appearance exists between the mature, compact, inner layers of the heart wood, called *duramen*, and the outer layers of the sap wood, called *albumen*. In the former, the fibers are firm and dense and possess a deep rich color, while in the latter the fibers are open, porous, and filled with sap and usually of a pale color. The sap wood possesses little strength, and the sap it contains is largely composed of a sugary substance which invites the attack of insects and hastens decay.

12. The age of a tree may be ascertained by counting the zones, when these are visible, but various causes occur which interrupt the growth, such as severe frosts, etc., causing a line of separation, and several lines may thus be formed in one year, which may lead to an erroneous estimate.

That part of the tree which is more fully exposed to the sun will be found to have wider layers than the other part; hence, the pith, or heart, is seldom in the center of the stem.

Soft woods usually possess wider zones than the hard woods, and it will be observed that much difference exists between the width of the zones in the same tree.

As in the animal kingdom, there are three periods of existence, infancy and youth, vigorous life, and declining vitality and decay; so a similar series exists in the vegetable kingdom.

When the tree is most vigorous, it produces the largest zones. In the case of the oak, this occurs between the twentieth and the thirtieth year, after which its productive power is gradually lessened, and as it grows older, the zones become smaller.

13. Between the inside of the bark and the woody layers is located the *cambium layer*, as shown at *d d*, Fig. 1, which consists of a cellular tissue like the pith, but contains, in addition to the cell sap, the rich life-giving secretion called *protoplasm*, without which the tree cannot live. This layer possesses the property of building up the woody formation by the product of ever increasing cells, and only by the vital energy of this layer, also called the *thickening zone*, can the tree increase in diameter.

14. The bark consists of three distinct layers. The inner or *bast layer e e* is composed of woody fibers combined with a cellular tissue, which retains a flexible, rubber-like elasticity and allows it to expand as the woody layers are produced by the cambium. The central layer

f f is comprised of prismatic cells and tubes filled with juices, while the outer layer *g g* is composed of a corky substance of cellular structure. During the growth of the tree there is a continual distending and separating of the fiber and cellular tissue composing the bark, which is renewed and strengthened by means of the cambium layer.

15. In the stem of several trees, especially the oak and the locust, we observe lines which radiate from the center of the tree; these are called medullary rays. When they connect the pith to the bark, as at *i i*, in Fig. 1, they are called *primary rays;* but where they extend through only a portion of the stem they are called *secondary rays.*

These medullary rays, generally called *silver grain*, when exposed on the surface of the cut lumber, consist of a series of vertical plates or sheets. Originally of cellular tissue, they have become flattened by compression until they resemble sheets of mica; they are not, however, continuous vertically, but are buckled and present a serpentine outline, when exposed on the edge as shown in Fig. 2. On the end-cut of the figure, the medullary rays are marked *a*, *a*, while the porous fibers of the zones are marked *b*, *b*, and the close or denser ones are marked *c*, *c*.

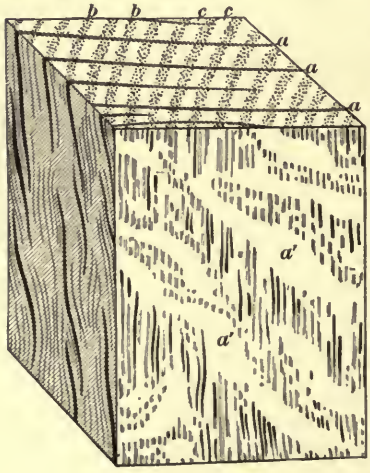


FIG. 2.

The appearance of the silver grain, or medullary plate, when cut nearly parallel to its direction is shown at *a'*, *a'*; it is the presence of these medullary rays which gives so much beauty to quartered oak. The rays are prominent also in

beech and sycamore, but are not so well defined in birch, chestnut, and maple.

16. The structure of the stem, as it presents itself to the observer on examining the end of an oak or ash tree of 13 years' growth, is shown in Fig. 3, in which the porous fibers or sap vessels of the coarser texture are shown at *a*, *a*; the closer texture at *b*, *b*; the primary medullary rays at *i*, *i*, and the secondary ones at *j*, *j*; the zone of the bark being shown at *c*, *c*. In a temperate climate the process of growth may be thus described: In the spring, the roots extract the juices (generally called *crude sap*) requisite for vegetable growth from the earth; the crude sap circulates from cell to cell and through the fiber tubes, and ascends and forms the leaves.

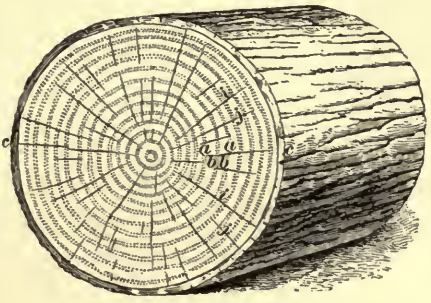


FIG. 3.

At the upper surface of the leaves, under the influence of light, chemical changes take place, the sap absorbing carbon from the air and becoming denser. After the leaves are fully developed, there is no further growth until the autumn, when the so called *elaborated sap* descends by the under side of the leaves, enters the branches and stem, and continues its descent principally between the wood and the bark, where, by the action of the cambium cells, it builds up a new woody layer or zone for that year, a portion being absorbed by the bark for its nourishment.

During this period the leaves fall off, and when the sap has ceased to circulate, the growth of the tree is suspended. In tropical climates, the circulation of the sap ceases during the dry season.

17. Midsummer and midwinter in temperate climates, and the dry period in tropical climates, are considered to be

the best seasons for felling the trees; in both cases it is the time when the sap has ceased to circulate.

18. For building purposes, the trees should not be felled until they have attained their mature growth, as already stated; nor should they be used after the tree has exhibited signs of declining vitality. The greatest number of trees arrive at maturity between 50 and 100 years, and commence to decline after 150 or 200 years. When the top of the tree ceases to send forth its full complement of leaves in the spring and bare branches remain, making it appear "stag-headed," it clearly shows a lack of nutritive power, and is a sure sign that it has begun to lose its strength and vitality. The timber then loses its elasticity and firmness and gradually becomes crisp and brittle.

19. Trees growing in the heart of the forest are generally straight and tall, as it is necessary for their leaves to receive sunlight and air sufficient for vitalizing the sap; the lower branches of these trees only last a few years, when they die and fall off. On the edges of the forest, the lower branches of the trees remain alive and active, so that timber cut from such places is knotty and cross-grained, while that cut from the inside trees is clear and straight grained.

20. Where streams are available, the logs are hauled or drawn to them, and floated to the mill; this immersion in the running stream makes the sap more soluble, and tends to make it more responsive to evaporation, during the process of seasoning; but if long immersed, the fiber loses its virtue and elasticity. To save the cost of hauling the waste material, portable engines and saws are frequently transported to the place where the logs are cut.

21. When the lumber is reduced from the dimensions originally cut from the log, it is said to be *resawed.* After lumber is planed at the mill, it is called *dressed* lumber, and is assorted into many grades.

The regular thickness of dressed lumber is $\frac{5}{8}$, $\frac{7}{8}$, $1\frac{1}{8}$, $1\frac{3}{8}$, and $1\frac{7}{8}$ inches, the thickness of the rough sawed material being $\frac{1}{8}$ inch greater than these measurements.

Where $\frac{1}{2}$-inch dressed material is required, it is usually made by resawing $1\frac{1}{4}$-inch boards.

22. In the body of sound, healthy trees there often occur circular seams, or cracks, where the layers have become separated from each other; these are said to be caused by the action of violent wind storms upon the stem of the tree during the formation of the woody layers, and are called *cup shakes*. They generally occur near the base of the stem, and in some cases can be detected in the standing timber by an abnormal increase in the bulk of the stem.

Where they occur, as at *a*, *a*, Fig. 4, there is much waste in cutting the material; where the shake is short, as at *b*, the loss is not great. Sometimes circular bands occur in the stem, in which the wood is of a softer and more spongy character than the surrounding layers, and which, in some cases, show signs of incipient decay. This condition is assumed to be caused by the action of sharp frosts upon the rising sap in the newly formed layers. When timber presents this appearance, it should be immediately rejected, as it will be short lived and will soon decay.

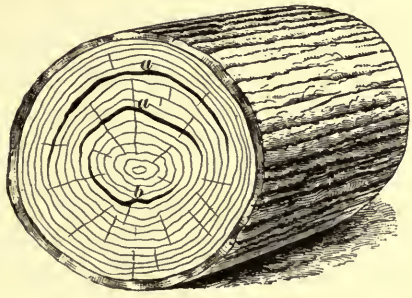


FIG. 4.

23. The soil in which timber is grown exercises an important influence upon its quality; where damp and marshy, the fiber is of a light, spongy character, the excess of water preventing the healthy action of the sap in forming firm and compact wood. Such soil is better adapted to the growth of light woods, as basswood, willow, and whitewood.

The hard woods thrive best on dry, clayey soils, while those of the pine group are best developed in sandy soils.

24. Exposure to prevalent wind storms in one direction tends to produce a twisted, spiral mode of growth. Timber possessing this character is of little value for building purposes, because, when cut into planks or scantlings, the fibers run obliquely across them, and, therefore, it possesses little strength.

25. Trees are subject to excrescences and tumors which deteriorate the value of the timber. These may result from the defective nature of the soil, the attacks of animals by gnawing, or by insects which bore into the fiber.

An excess of sap in some parts of the tree shows on the outer surface by the formation of pus, or matter, which expends the virtue of the sap and deteriorates the value of the surrounding fiber. This disease may spread, and ultimately cause the death of the tree. Trees are also affected by a brownish *rust*, which is caused by rain water obtaining access to the cambium layers by means of clefts or rifts in the bark, and which, changing the character of the sap, reduces the wood to a powder.

These clefts in the bark may be the result of an unusually dry season and a rapid rising of the temperature, causing strains greater than the bark can resist; or they may be caused by severe frosts, which, acting on the sap, cause it to expand and rend the bark.

Frequently the clefts penetrate the sap wood also, and extend into the perfect woody layers. Though these separations of the fibers may be healed up by subsequent growth, they still cause a deterioration of the wood adjacent to them.

26. There is a species of insects which deposit their eggs in the clefts of the bark, where they are hatched. These insects are a kind of beetle, and, like the moth and butterfly, pass through a larval and pupal stage of development.

The *larva*, or grub, which is hatched from this egg, immediately bores into the sap wood, which furnishes its food.

The juices of the sap wood are composed of various substances—acids, albuminoids, gums, sugar, starch, oils, and water—on which the grub feeds and thrives, until it reaches its full size, when it weaves a *chrysalis*, or envelope-like sheath, and enters the *pupa* stage. This is a state of rest, in which the grub exists without nutriment while its organization is being elaborated, when it rends the envelope and emerges a perfect insect.

As the larval period extends for months, and sometimes years, during which the grub steadily eats its way into the fiber, it will be seen how destructive the operations of an innumerable army of these workers are, when once they obtain an opportunity to attack the timber.

Were it not for the warfare waged on these herbivorous insects by birds, squirrels, lizards, etc., which eagerly devour them, and for the action of frosts and rains, tending to prevent their excessive development, few trees would reach a state of maturity and be able to furnish sound, solid timber.

Where timber has been attacked by insects, the part affected, as well as the adjacent fiber, is rendered entirely useless for building purposes.

Where the stem of a tree is regularly formed, and shows a perfect bark, free from rifts and excrescences, it may be assumed that it will produce perfect timber.

27. In order to keep the timber perfect, however, the greatest care must be exercised in piling the timber, so as to prevent the attack of parasitic plants, called *fungi*. These constitute a lower order of plant life, which, instead of independently assimilating and digesting nourishment extracted from the soil, derive their nutriment from the organic substance of others.

The fungi are developed from *spores*, or life germs, which insinuate themselves into cracks and crevices, and propagate very rapidly. The vegetative system of these plants consists of *filiform*, or thread-like tubes, which form the roots and extract their food from the substance of the timber.

The interwoven tangle of these root hairs forms what is

called the *mycelium*, which may retain the thread-like appearance of the roots, when it is defined as *filamented;* it may become so closely woven as to appear like a sheet of paper, when it is called *membranous;* or when it presents an appearance like moss, with stems and branches, in which the fibers have become firm and hard, it is called *fibrous.*

As the mycelium grows and reaches maturity it sends out thread-like shoots of closer texture than the roots, and these shoots produce the spore cases which envelope the germinal seed.

The conditions which are considered favorable to the reception and germination of the spores of the fungi, are warmth, moisture, the exemption of sunlight, and the presence of elements suited for their nutrition.

The substance of the timber is attacked by the mycelium either by robbing it of the valuable juices contained in its fiber ducts, reducing the texture to a dry, lifeless, sponge-like condition, or by secreting peculiar juices which act on the woody tissue and convert it again into *cellulose* (the starchy substance of its original formation), and which is dissolved and absorbed by the parasite, thus breaking down or decomposing the fiber, and resulting in what is known as *decay* or *rot.*

The conditions being favorable, the work of this insidious foe continues until the entire fabric is reduced to powder. The parasite attacks the living tree as well as cut timber, and in both cases the results are the same.

28. Timber should be piled in high and dry locations only, and should be kept well up from the ground on staging and strips placed between the beams or boards, so as to allow of a thorough circulation of air around every side of the timber.

No vegetation should be allowed to grow under or around the pile, as it would create conditions favorable for the retention and germination of the spores of the fungi.

The surface of the ground should be covered with ashes or gravel, which will prevent vegetable growth and also keep the surface free from moisture.

Timber deteriorates very rapidly in quality if it becomes heated, which may arise from the material being closely piled together or from being placed in a confined situation; in either case the sap is prevented from evaporating and soon begins to ferment, and causes the fiber to show signs of decay.

The decomposition of the fiber is also caused by alternate dampness and dryness, and is forcibly illustrated by the action on fence posts, which, although sound above and below the ground line, soon give way at the parts thus affected.

29. Wounds, caused by the branches of the trees being broken off close to their roots in the stem, often result in the rotting of the knots, as well as the surrounding fibers. This rotting is caused by the decomposition of the sap which accumulates and covers the wounds, and the *knots*, as the roots of the branches are called, assume a spongy appearance, which is called *druxy*. When the druxy knots are of a brown, fox-like color, the rot usually penetrates farther into the timber and is more likely to seriously affect the healthy wood.

30. In selecting timber for building purposes, the principal points which should be carefully observed, are straight grain, freedom from large or loose knots, wind and heart shakes, and the presence of the characteristics which indicate any of the diseases and imperfections of the fiber previously described. When cut, the sawdust should not be clammy or dough-like, but granular, or meal-like, crisp, sparkling, and free from stringy fibers. The surface of the sawed material should be clean and lustrous, presenting a firm and bright appearance, and free from spongy or woolly fibers, which indicate lack of vitality. The heart wood should be sound and mature, and the sap wood, or layers next to the bark, should be entirely removed. The wood should appear uniform in texture, and when cut should smell sweet; a disagreeable smell is a sign of decay. When the wood is planed, it should have a silky, shining surface; the shavings should come off like ribbons and stand twisting around the fingers.

When the surface appears dull and chalky, and the shavings are brittle and short, it may be considered that the stock lacks much of the virtue it ought to possess. Good material should be uniform in color; when blotchy or discolored, it signifies a diseased condition, which may be due to defective development, or be caused by piling the lumber close together after it has been sawed. The black and blue streaks and patches, which often occur in lumber, are the result of close piling, which causes the sap to sour or ferment. The defective pieces should be cut out and only such portions as appear sound and perfect should be used in work where strength and durability are essential requirements.

31. Heart shakes, sometimes called star shakes, are rifts, or cracks, which radiate from the center of the tree, as shown at *a*, *a*, Fig. 5. They are common in nearly all classes of timber, and are caused by the shrinkage of the layers, incidental to loss of vitality; after the period of maturity has been passed and decline has begun, the outer rings being more active, derive their nutriment by absorbing the juices from the heart wood, thus causing a gradual but sure loss of its strength and virtue.

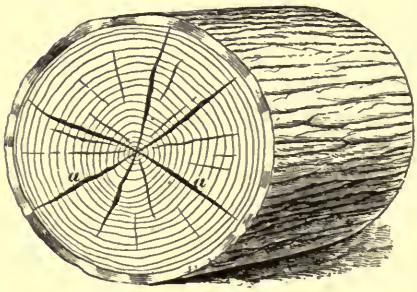


FIG. 5.

32. In converting timber into such sizes as are required for constructive purposes, there are several conditions governing the operation, which, if not understood, or if ignored, result in a loss of material, as well as affect the future conduct of the several pieces cut from the log.

It is seldom that the carpenter is required to use the timber in the round form given to it by nature, unless it is in the construction of rough and rustic work. Round timbers are also used in constructing pile foundations, and for props and supports when shoring buildings—the term *shoring*

signifying a temporary disposition of timbers to afford support and rigidity to any mass or structure, but, specifically, where alterations of original conditions are being effected. They are also used for scaffolding purposes, in which both the vertical and the horizontal portions are lashed together by means of ropes.

Where stock of variable widths, but of equal thickness, is desired, the log would be converted into planks, as shown in Fig. 6, by a series of saw cuts, as *a b*, *c d*, *e f*, etc., parallel to each other, the edges of the planks being afterwards squared by cutting off the *waney* or beveled portions, which formed the curved surface of the tree.

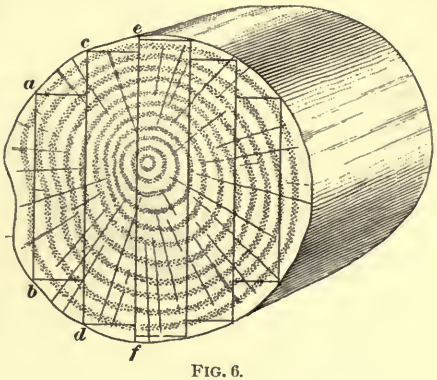


FIG. 6.

Where a large number of planks of uniform width is required, the end of the log would be marked, and cut on the line shown in Fig. 7, the portions *a*, *a*, called slabs, being waste material, although sometimes used for building fences, and for siding on rustic cottages, etc.

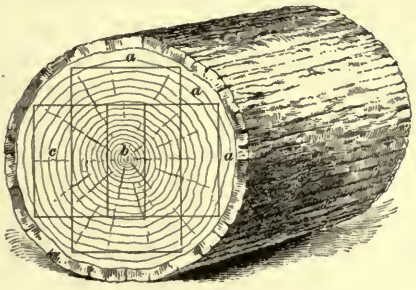


FIG. 7.

33. The manner in which the annual rings of growth are disposed on the end section of the plank, has a great influence on its behavior, after having been cut from the log. During the process of *seasoning* the lumber, or the drying and hardening of its fibers by the evaporation of the natural sap, there is an ever prevalent tendency for the boards or planks to curl and warp,

particularly, if the process is too rapidly enforced and special care is not taken to pile the material so as to allow free circulation of air, and at the same time have it stacked so that its weight will help to keep the boards flat.

34. The cause of this tendency to curl will be understood by reference to Fig. 8, in which is shown the end sections of two boards cut from different portions of the tree. At *a* it will be observed that the annual rings are nearly at right angles to the surfaces of the board, while at *b* they cross the surfaces obliquely and become nearly parallel to the faces. After the boards have been cut and have commenced to dry, owing to the evaporation of the sap, the sap ducts and fibers begin to contract and shrink; the form taken by the board in shrinking will be governed by the length of the annual rings on the section. In *a* the rings are practically of the same length, and the medullary rays being nearly parallel to the surface of the board, the faces will remain straight and true across their width, while in *b* the inner ring is shorter than the outer one; hence, the outer one will shrink more, causing the surface farthest from the heart of the tree to assume a concave form. This effect is further increased by the fact that the nearer the heart, the more dense and mature is the fiber, so that portions cut adjacent to it shrink less than those which are farther from it. Where a tree is twisted in its growth—that is, where the fibers seem to twist spirally around the stem in the height—it is impossible to cut boards from it which will not warp and wind, not only while they are seasoning, but also whenever affected by changes in temperature.

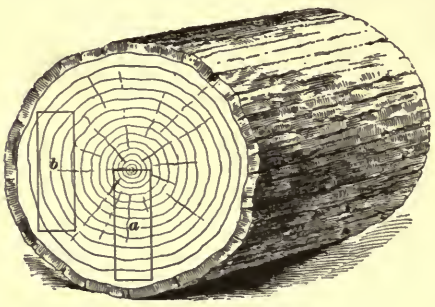


FIG. 8.

35. As has been shown, boards having the annual rings disposed as at *a*, are less liable to shrinkage and curling, and if the timber is rich in medullary rays, the element of beauty is also enhanced; furthermore, such boards, having only the edges of the laminations exposed, wear better and more evenly than where the leaf-like figure of the grain is shown on the surface, as it would be in the case of the board *b*.

METHODS OF SAWING.

36. In order to obtain as many boards as possible from the tree, which possess the many merits arising from this disposition of the rings on the end section, a method of first cutting the logs into quarters, and then reducing them to the required sizes, is adopted.

This method is shown in Fig. 9, where *a b* and *c d* are lines showing the first saw cuts which divide the log into four quarters, *a c*, *c b*, *b d*, and *d a*, each of which is then sawed into plank by some one of the methods shown, according to the purpose for which the lumber is intended and the economy of the material, which it is necessary to observe.

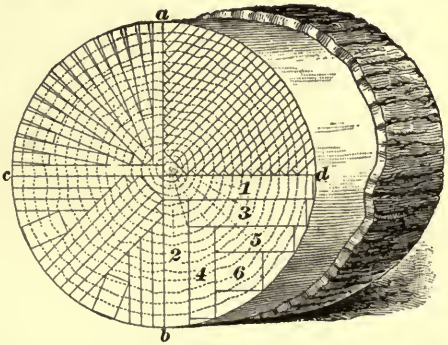


FIG. 9.

The quarter, sawed as shown from *a* to *c*, gives by far the best results, as the annual rings cross the plank nearly at right angles to its face, and the medullary rays being parallel to this face will exhibit the lines of the silver grain, so sought and admired in quartered oak. But it is not economical in material, and requires more time and attention to divide it, than does any of the other methods.

The waste of material is over twenty-five per cent., and, though this waste can often be utilized, it is usually counted

as loss in estimating the amount of timber which can be cut from a log. The time required to reduce this quarter to plank is thirty per cent. more than is required to reduce the quarter *c b*, and fifty per cent. more than the quarter *d a*. Therefore wood quartered in this manner is expensive, and its use is confined almost exclusively to furniture and fine cabinet work.

The method used in sawing the quarter from *c* to *b* is, as above shown, much more economical in time, though the waste of material is about the same. These waste pieces, however, are much larger and fewer than in the former case and can usually be utilized to better advantage. This is the usual method of cutting hardwood logs, and lumber produced by this method is used for all ordinary high-grade work in carpentry and joinery, especial attention being given to the position each plank occupied in the original log, according to the purpose for which it is required.

The method of sawing shown from *a* to *d* can hardly be called *quartering* in the sense we consider the results of that term. It is somewhat of an improvement on the method of bastard sawing, shown in Fig. 6, but there is but one-fifth of the finished lumber that presents the advantages of beauty and durability secured by either of the two former methods of sawing, and this fifth is generally selected by the dealers, and classed with the plank produced by the middle cut of the section from *c* to *b*. The other four-fifths is used almost entirely in cheap furniture and for the interior finish and trim of houses, where the terms *oak floors* and *hardwood trim* sound very well in the description, but refer to details which would give better service and be more in keeping with the character of the building, if constructed of the less aristocratic sounding pine or spruce, which had been reduced from a properly sawed log.

The method shown at *b d* is for securing large pieces, and the heavy planks are cut in the order their end sections are numbered. Numbers *1* and *2* are the choice pieces, and should always be selected for floorbeams, where a long span demands a beam that is not liable to warp or twist.

The selection of certain cuts for particular purposes, will be considered when those purposes are taken up for discussion, and attention is here again called to the careful study of Figs. 6, 7, 8, and 9, as illustrating the influence which the original position of a stick of timber in the tree has upon its subsequent behavior.

SEASONING.

37. The process of evaporating the sap, or the drying out of lumber, is effected after it has been sawed into planks, joists, studs, etc., and two methods known respectively as **seasoning** and **kiln-drying** are recognized as suitable and efficient for the purpose.

In the first of these, the boards are placed in the open air in large square piles, with narrow strips between the layers; a free circulation thus takes place throughout each pile, and the lumber remains in this position from two to four years, according to its ultimate purpose—two years being considered adequate for joists, studs, sheathing, and other ordinary framing material, while work intended for trim, doors, sashes, and other products of the joiner's skill, should season for four years, or even more, according to the class of material.

Kiln-drying is effected by piling the lumber, as above described, in chambers, or kilns, within which a circulation of air is maintained at a temperature of about 140° F. and at a speed of about 40 miles per hour. Vacuum pumps are used to produce this rapid circulation and to remove the moisture as it evaporates from the boards.

In this manner, lumber not over 2 inches in thickness can be thoroughly dried in about forty-eight hours, which is certainly a great saving of time, but the result is acquired at the expense of a loss of vitality of the material.

38. Kiln-dried lumber lacks the toughness and elasticity retained in the seasoned material, has a greater affinity for atmospheric moisture, and is often subject, especially in the softer woods, to what is known as *dry shrinkage*—that is, a

shrinkage caused by the gradual closing together of the cell walls from which the moisture was evaporated in the kiln, leaving the cell in a vacuous, or hollow, condition. This *dry shrinkage* does not take place until after the material has been worked, and regardless of the position of the zones, or annual rings, the wood becomes concave on its freshly cut surface.

The cause of this is that the outside, or surface, tissue of the material is dried first, and thus forms a sort of casing, or crust, which holds the inner fibers in position, and when this surface is removed through the agency of the saw or plane, the interior fibers, being thus relieved of their protecting casing, gradually close on the exposed side and cause the wood to bend, or warp.

This will also occur in weather-seasoned wood which has been placed in one position for a long period and remained uncut or unworked. Thus, the top of an old table will almost invariably become concave if it is planed off to get a new surface.

39. Good results are obtained by the process of subjecting weather-seasoned boards of two or three years' exposure to the kiln-drying process before they are used in a building, or immediately after they are worked into flooring, siding, ceiling, etc. Boards thus treated and kept perfectly dry thereafter can be used in the trim and finish of a building, and if primed and painted, or filled and varnished as soon as possible after they are in place, a good, durable, and unchanging job can be assured.

PROPERTIES OF DIFFERENT KINDS OF WOOD.

40. Wood, as a building material, is divided into three general groups, namely, the *evergreen* class, the *tropical* class, and the *hardwoods*.

In the first of these are classed the pine, spruce, hemlock, cedar, cypress, etc. The tropical woods include palm, rattan, bamboo, etc. The hardwoods are oak, chestnut,

walnut, locust, maple, hickory, ash, boxwood, whitewood, and a number of others.

Each of these woods has peculiarities and characteristics which render it fit and useful for some building purposes, and utterly unfit and useless for others.

THE EVERGREEN CLASS.

41. White pine, commonly known as *pine*, or sometimes referred to as *northern pine*, to distinguish it from the species described below, is a tree common in the northern part of the United States and in Canada. It furnishes a light, soft, and straight-grained wood of a yellowish color, but is not as strong as other woods of the same class, and in building is used, principally, as a finishing material, where a good, durable, but inexpensive job is required. As a material for patternmaking it has no equal, and its power of holding glue renders it invaluable to the cabinetmaker and joiner.

42. Georgia pine, also known as *hard pine*, *pitch pine*, and occasionally as **long-leafed** pine, which is, in reality, the best name for it, is a large forest tree growing along the southern coast of the United States, from Virginia to Texas, and extending only about 150 miles inland. Its annual rings are smaller than those of the white pine, and have a dense, dark colored and resinous summer growth, which gives the wood a well marked grain.

The wood is heavy, hard, strong, and, under proper conditions, very durable. For heavy framing timbers and floors it is most desirable, and on account of its grain is sometimes used for the trim of unimportant rooms. It rapidly decays in a damp location, and, therefore, cannot be used for house sills, or as sleepers or posts which are in contact with the ground, but if situated in a dry, well ventilated place, it will remain practically unchanged for over a century.

Great care should always be exercised in specifying work to be done with Georgia pine, as in many localities this wood is confused with another material variously known as

Carolina pine, *yellow* pine, and *southern* pine, which is greatly inferior to it in every respect.

The *Carolina* pine is not a *long-leafed* pine at all, and is neither as strong nor as durable as the Georgia pine. In appearance it is somewhat lighter than the long-leafed pine, and the fiber is softer and contains less resin than the regular *hard*, or *pitch*, pine.

43. **Spruce** is a name given to all the wood furnished by the various species of the *spruce fir tree*. There are four varieties of the wood, known as *black* spruce, *white* spruce, *Norway* spruce, and *single* spruce. *Black spruce* grows in the northern half of the United States and throughout British America. Its wood is light in weight, reddish in color, and though easy to work, is very tough in fiber and highly desirable for joists, studs, and general framing timber. It is also greatly used for piles and submerged cribs and cofferdams, as it not only preserves well under water, but also resists the destructive action of parasitic crustacea, such as barnacles and mussels, longer than any other similar wood.

44. *White spruce* is not so common as the above described variety, though when sawed up into lumber it can scarcely be distinguished from it. Its growth is confined to the extreme northern part of the United States and to British America.

Norway spruce is a variety growing in central and northern Europe and in northern Asia, and its tough, straight grain makes it an excellent material for ships, masts, spars, etc., as well as the more ordinary purposes of house building.

Under the name of *white deal* it fills the same place in the European woodworking shops as white pine does in America.

Single spruce grows in the central and the western part of the United States. It is lighter in color, but otherwise its properties are similar to the black and the white spruce.

45. **Hemlock** is similar to spruce in appearance, though much inferior as a building material. The wood is very brittle, splits easily, and is very liable to be *shaky*. Its grain is coarse and uneven, and though it holds nails much more

firmly than does pine, the wood is generally soft and not durable.

Some varieties of it are better than others, but in commerce they are so mixed that it is difficult to obtain a large quantity of even quality. Hemlock is used almost exclusively as a cheap, rough-framing timber.

46. White cedar is a soft, light, fine-grained, and very durable wood, but lacks both strength and toughness. Its durability makes it a desirable material for shingles, and also for tanks in which water is stored, and these are about the only purposes for which it is used in house building, though it is used largely for other purposes, such as boat-building, cigar-box manufacture, and cooperage.

47. Red cedar is a smaller tree than white cedar, and of much slower growth. The wood is very similar in texture to white cedar, but even more compact and durable. It is of a reddish-brown color, and possesses a strong, pungent odor, which repels insects. Its extreme durability makes it valuable for posts, sills, sleepers, etc., in contact with the ground, and its strong odor renders it extremely serviceable as shelving for closets, and linings for chests and trunks, when the exclusion of moths and other insects is desired.

48. Cypress is a wood very similar to cedar, which grows in southern Europe and in the southern and western portions of the United States. It is one of the most durable woods, and is well adapted for outside use.

In the northern part of the United States its use is confined, almost exclusively, to shingles, but in the South it is used as extensively as pine is in the North.

49. Redwood is the name given to one of the species of giant trees of California, and is the most valuable timber grown in that state. It grows to a height of from 200 to 300 feet, and its trunk is bare and branchless for one-third of its altitude. The color is a dull red, and while the wood resembles pine, and is used generally in the West for the same purposes as pine is in the East, it is inferior to pine, on

account of its peculiarity of *shrinking lengthwise* as well as crosswise. It is used largely for railroad ties, fence posts, telegraph poles, and other purposes where durability under exposure is required. As an interior finishing material it is highly prized, as it takes a high polish, and its color improves with age.

THE HARDWOOD CLASS.

50. The **hardwood** group is headed by the **oak** as typical of its class, nearly all others being compared with it in regard to hardness, durability, and strength.

51. *White oak* is the hardest of the several American species of the oak tree, and it grows in abundance throughout the eastern half of the United States. It furnishes a wood which is heavy, hard, cross-grained, strong, and of a light yellowish-brown color. It is used where great strength and durability are required, as in framed structures, ship building, cooperage, and carriage making.

Red oak is similar in nearly every respect to white oak, except in its grain and color, the grain being finer and closer and the color darker and redder. It is also about 12 per cent. softer.

English oak is similar to the American oaks in color, texture, and appearance, but is superior to them for such structural purposes as ship building and house framing.

The structure of the fiber, and the large, thick, and numerous medullary rays, make oak especially prized as a material for cabinet work and furniture, when the log is *quarter-sawed.* The silver grain and the high and durable polish which the wood is capable of receiving, make it one of the most beautiful used in joinery and cabinetwork.

52. **Ash,** the wood of a large tree growing in the colder portions of the United States, is heavy, hard, and very elastic. Its grain is coarse, and its color is very similar to that of red oak, which it also resembles in strength and hardness.

Ash is used sometimes for furniture and cabinetwork,

where it is often supposed to be an imitation of oak, but it is never so strongly marked in the silver grain as oak, and its tendency, after a few years, to become decayed and brittle renders it unfit for structural work.

53. Hickory is the heaviest, hardest, toughest, and strongest of all the American woods. The medullary rays are very numerous and distinct, and produce a fine effect in the quarter-sawed plank. The flexibility of the wood, together with its toughness and strength, render it valuable in the manufacture of carriages, sleighs, and implements requiring bent-wood details.

As a building material, it is unfit for use: first, on account of its extreme hardness and difficulty of working; and second, on account of its liability to the attacks of boring insects even after the fibers have been filled and varnished.

54. Locust is one of the largest forest trees in the United States, and furnishes a wood that is as hard as white oak. It is composed of very wide annual layers, in which the vessels are few but very large, and are arranged in rows, giving the wood a peculiar striped grain.

Its principal use is in exposed places where great durability is required, while for posts for buildings and fences in damp locations it has no superior.

Its hardness increases with age, and on this account it is used for turned ornaments and occasionally in cabinetwork.

55. Black walnut is one of the finest and largest timber trees peculiar to the United States. Its wood is heavy, hard, and porous, and its dark, purplish color is marked by a beautiful wavy grain. Strong, durable, and not subject to the attacks of insects, it, at one time, furnished the most popular wood for interior decoration and fancy cabinetwork, but its present use is confined generally to small cabinetwork and gun stocks, which latter are made almost exclusively of this material.

The irregular and knotted roots of the tree produce, in the wood cut from them, an appearance called **burl.**

56. Cherry.—The wood of the *wild-cherry* tree is a moderately heavy wood, hard, and very durable. The annual rings are wide and even in their structure, while the medullary rings are fine, numerous, and of a light-red color, giving the wood a close, fine grain, of a brownish-red color, which is susceptible of an exceedingly high polish, and is, therefore, much used in cabinetwork.

The close and even grain in cherry makes it particularly adaptable to imitations of more valuable and less abundant woods.

Cherry stained black to imitate *ebony* cannot be detected from the genuine material except by scraping off the polished surface; and as a substitute for mahogany and rosewood it makes a fair imitation. For this reason it is largely used for piano cases, book shelves, furniture, and other general cabinet work which is turned out in quantity and afterwards stained to imitate various other materials.

Cherry does not respond as quickly to changes of temperature or dampness as do most other woods, for which reason, it is, in many instances, more serviceable as an imitation of ebony, mahogany, or rosewood than would be the genuine material.

57. Birch is a wood strongly resembling cherry in its texture and, in some of its species, also in its color. *Black*, or *cherry*, birch furnishes the best lumber, and most strongly resembles the cherry in color, texture, weight, and strength, but it is not as durable, and is much more affected by atmospheric influences.

White, or *paper*, birch is chiefly noted for the quality of its bark, which can be stripped from the tree in long, paper-like sheets. It was extensively used by the Indians to thatch the roofs of their huts and to construct their canoes. The wood is used principally in the manufacture of wood-pulp paper, though small turned articles, such as spools, cups, spoons, etc. are manufactured from it.

58. Maple is a large-sized timber tree, which furnishes a light-colored, fine-grained, hard, strong, and heavy wood.

The annual growth is narrow and close, but, scattered through it, small vessels may be seen on careful examination. The medullary rays are small and distinct, giving to the quarter-cut lumber a clearly defined silver grain. Two other characteristics of the grain are observed, especially in old trees, and are known as *curly maple* and *bird's-eye maple*. The former is a waviness of the grain similar to the *burl* obtained from the root timber of the walnut tree, while the bird's-eye is an effect produced in old trees by the circular inflexion of the fibers. In appearance the plank is covered with numerous small spots, similar to minute knots, and strongly resembling bird's eyes, whence it derives its name. Though both the *curly maple* and the *bird's-eye* are practically distorted fibers and materially reduce the strength of the wood, they are highly prized in the cabinetmaker's art, as they lend to the polished surface a variegation and impart a beauty equaled by few other materials.

59. Chestnut, a large forest tree common to the eastern part of the United States, produces a comparatively soft, coarse-grained wood, which, though very brittle, is exceedingly durable when exposed to the weather.

It will not stand variations of slowly evaporating moisture as well as locust, and is, therefore, not so well suited for fence posts and sills laid in contact with the earth; but for exposed structures and sleepers laid in concrete or sandy soil, it affords a material much more easily worked than locust, and nearly as durable as cedar.

At the age of 50 years the tree is in fine condition for cutting, previous to which the wood is likely to be composed of large cells filled with moisture, which do not dry out without impairing the quality of the timber. On the other hand, if the tree is not cut at 50 years, it is almost sure to become decayed in the heart wood, and thereby rendered unfit for use.

60. Butternut is a small species of walnut, whose wood is of a light color, and possesses a strongly marked grain. Its lumber can be secured only in short lengths, and though soft and easily worked with edged tools, it will not split

easily, resists moisture, and remains comparatively unaffected by heat until the wood begins to char. It is not suitable for a framing material, but is sometimes used in cabinetwork on account of its susceptibility to an extremely high polish.

61. Beech is the wood of a large forest tree growing in the eastern part of the United States, and in Europe. It is used but slightly in building, owing to its tendency to rot in damp situations, but it is often used, especially in European countries, for piles, in places where it will be constantly submerged.

It is very hard and tough, and of a close, uniform texture, which renders it a desirable material for tool handles and plane stocks, a use to which it is often put.

It is occasionally used for furniture on account of its susceptibility to a high polish, but is too brittle for very fine work requiring strength.

62. Whitewood, so called from the purity of its color, is the lumber of the tulip tree, a large, straight forest tree abundant in the United States. It is light, soft, very brittle, and shrinks excessively in drying. When thoroughly dry it will not split with the grain, and in even slight atmospheric changes will warp and twist exceedingly. Its cheapness, ease of working, and the large size of its boards cause it to be used in carpentry and joinery, in many places where it is utterly unsuited.

63. Buttonwood, also called **sycamore,** is the name given in the United States to the wood of a species of tree generally known as **plane tree.** The wood is heavy and hard, of a light brown color, and very brittle. Its grain is fine and close, but, though susceptible of a high polish, it is not much used in general carpentry or joinery, as it is very hard to work and has a strong tendency to warp and twist under variations of temperature. In damp places it will soon show signs of decay, and is, therefore, unfitted for any but the most protected positions.

64. **Apple** and **pear** trees furnish wood much used for tool handles, plane stocks, and small turned work, but neither is much used in building.

The irregular-twisted branches of the former are sometimes used in ship building, from which to saw the ribs of a boat, taking advantage of the natural bend of the wood to form the rib, but for other building purposes it is rarely used, as the lumber runs in short, irregular pieces, with a crooked and twisting grain.

Pear wood is sometimes used for carved panels in cabinet-work, on account of its yielding so easily to edged tools.

65. **Boxwood** does not, as its name might imply, enter in any way into the manufacture of boxes. It grows in Europe and Asia, along the coast of the Mediterranean Sea, is close-grained, yellow in color, and very desirable, on account of the absence of shrinking or warping tendencies, for small carved or turned work, such as spindles and chessmen, and is particularly useful in wood engraving, for which purpose it has no equal. As a building material it is very rarely used.

66. **Basswood** is the name given to the timber of the American *linden* tree. In color, texture, and general appearance, it strongly resembles pine, but is much more flexible. On this account it is sometimes used for curved panels in furniture and interior decorations, as well as in carriage manufacture for the curved surfaces of various vehicles.

It has a great tendency to warp, and will shrink both across and parallel with the grain, rendering it undesirable in building, unless strengthened by battens or a hardwood lining.

67. **Mahogany** is the wood of a large, handsome tree which is a native of the West Indies and Central America. Its color, grain, and hardness vary considerably according to the age of the tree and the locality of its growth.

It is a wood of great commercial value, on account of its great strength and durability. The straight-grained varieties do not warp or shrink materially with atmospheric

changes, and are used extensively as frames for fine machinery, work benches, etc.

The cross-grained species, on the contrary, warps and twists to a remarkable extent, and though highly prized as a material for panels and furniture, it can be used to advantage only when veneered upon some more reliable wood. Ordinary straight-grained mahogany is not a very hard wood, and when freshly cut, its color is a light, yellowish tan, but with age it becomes darker and exceedingly hard and brittle.

68. **Rosewood** is the heavy, hard, and brittle product of several trees native to the tropical countries. It has a beautiful grain, alternating in dark brown and red stripings, which, when subjected to a high polish, make the surface one of the handsomest products of the vegetable world. The solid wood is used for handles to fine tools, but for few other purposes. As a veneer, it is applied to all kinds of cabinet, furniture, and joinery work, where richness, elegance, and durability are desirable, regardless of expense.

69. **Ebony,** a dark, almost jet-black wood, native in the East Indies and parts of Africa, is a heavy, strong, and exceedingly hard wood, with an almost solid annual growth. It takes an exceedingly high polish, and is used mostly for small turned and cabinetwork, though its veneers are applied to interior work, and also to fine furniture. It is not used as much for general interior trim and paneling as formerly, on account of its expense, and the somber appearance that a black surface must necessarily lend to a room, and besides this, the imitation of it in stained cherry is much cheaper and so like the original that it would take an expert to detect the difference.

70. **Lignum vitæ** is another exceedingly heavy, hard, and dark-colored wood, with an almost solid annual growth. It is very resinous, difficult to split, and has a soapy feeling when handled.

Its color is dark brown, with lighter brown markings, and it is used mostly for small turned articles, tool handles, and the sheaves of block pulleys.

CLASSES OF FRAMED STRUCTURES.

71. Carpentry, as applied to house building, relates to the construction of the rough timber framework of the building in all its parts, from the foundation to the roof. In buildings which are partly constructed of stone or other material outside the carpenter's province, the carpenter is usually called upon to furnish, and generally to set, all centers, templets, wood lintels, etc. that may be required for arches, square openings, and angles.

72. Buildings constructed entirely of wood, above the foundations, may be divided into two general classes; viz., *braced-frame* and *balloon-frame* structures.

A **braced-frame** building is one in which each piece of the structure is carefully fitted and fastened to every other piece it comes in contact with, and the whole skeleton is thereby made stiff and secure before any of the covering material is applied.

A **balloon frame,** on the contrary, is one in which the timbers are simply nailed together; it depends, therefore, entirely upon the sheathing, or outer covering, for strength and security.

73. The former method is the one used in ancient times, and had its origin when all nails, bolts, and iron straps were made by hand, and required more labor to produce them than the cutting of mortises, or the halving of joints. With the advent of machine-cut nails came the balloon frame, which, though it may be a somewhat flimsy affair in itself, is, after the sheathing is on, much stronger and stiffer than the regular, or braced frame, and costs about half the money.

There are still, however, classes of buildings where the balloon frame is hardly suitable, and there are also instances in balloon framing where the joints require close and accurate fitting. To effect the best construction in a building, therefore, requires not only a knowledge of the kind of material best suited to the place and purpose, but also a knowledge of the proper size or sectional area of each piece,

to withstand the strain that may come upon it, and the proportions of its dimensions to give the required area and at the same time suit the position in which it is to be placed.

74. The fitting together of these several pieces of the structure demands a knowledge of the proper kind of joint required in each particular case; an understanding of the conditions likely to arise which would tend to render the joint more or less ineffectual, such as shrinkage, dry rot, or warping; and the ability to compensate or prevent any evil results which such conditions would entail.

JOINTS.

75. The simplest joint between two pieces of wood is the square **butt joint** shown at (*a*), Fig. 10, where the timber *b* effects a butt joint with the timber *a* on the line *k c d*. This joint, called a *barefoot* joint, is used in balloon-frame construction where the studs rest upon the sills or partition caps, and are secured in position by *toe-nailing*, as shown at *e*. An oblique butt joint is shown at (*b*), Fig. 10, where *l m n* and *o p q* are the lines of the joints between the timbers *f* and *j* and the timbers *g* and *j*. This form of the joint is sometimes used for placing rafters upon the plate, or against the ridge board, and must always be securely toe-nailed, or a movement in the position of the foot *l m* or *p q* would throw the joint out of alinement.

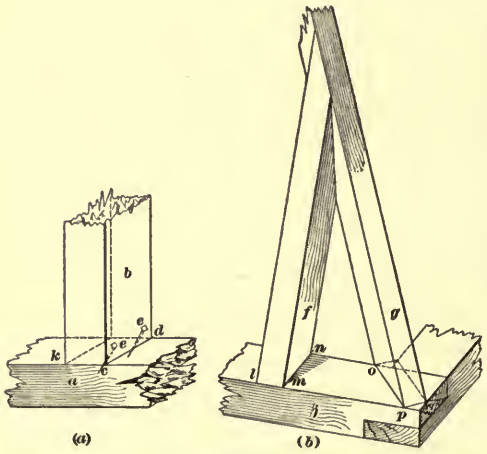


FIG. 10.

76. Mortise and Tenon.—Where greater strength and security than can be obtained from the butt joint is required, we make use of the *mortise-and-tenon joint*, shown in Fig. 11. A rectangular hole *a b c d*, called a *mortise*, is cut into one of the timbers, as *w*, and on the end of the other timber *y* is shown the projecting pin or *tenon e f g*, which fits into and exactly fills the mortise.

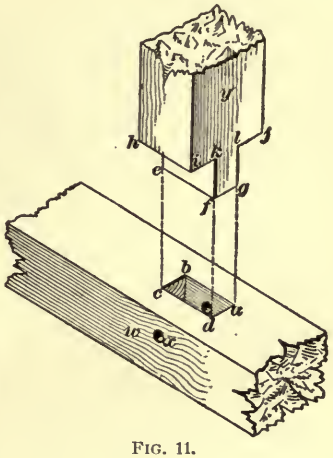


FIG. 11.

The proportion of the width *d a* of the mortise to the thickness of timber in which it is cut is one-third, and the mortise is cut into the center of the thickness. Or, if one timber is larger than the other, they are usually so framed that, when brought together, one face of each piece will be flush.

77. These mortise joints are nearly always secured in place by means of a *draw-bore pin*, which is inserted as follows: After the mortise is cut, and the tenon is accurately fitted to it, a hole is bored in the timber, squarely through both cheeks of the mortise, as shown at *x*, in Fig. 11. The position of the hole *x* is accurately marked on the tenon *e f g*, and a hole is then bored through the tenon *but located from* $\frac{1}{16}$ *inch to* $\frac{1}{8}$ *inch nearer the shoulder* than the marks made through the hole in the mortise. When the tenon is now inserted in the mortise, the relative position of the holes will be somewhat as shown at (*a*), in Fig. 12, which is an enlarged section through the girt and corner post on the line *x y*. A wooden pin is then driven through these holes, and by forcing them into line it brings the shoulders of the tenon *p* tight up against the cheeks of the mortise *q*, thus making the joint firm and secure, as well as free from any liability to work itself loose. This wooden pin, usually called a *tree-nail* or *draw-bore pin*, should be cut from a piece of straight-

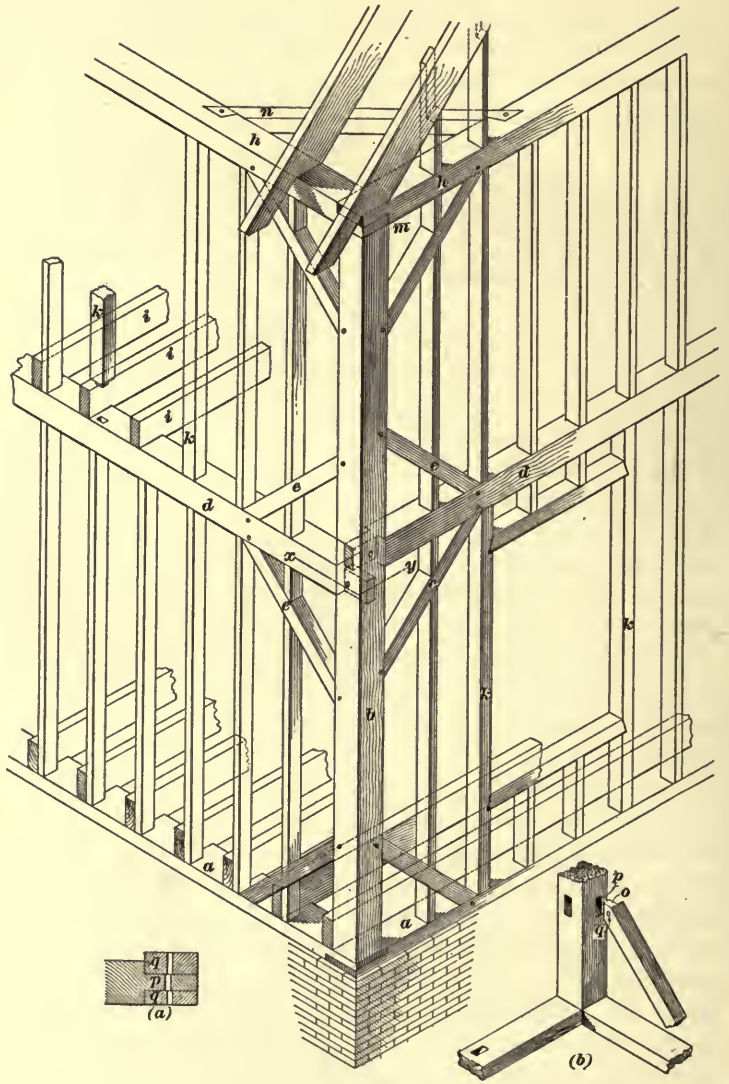


FIG. 12.

grained, tough, and durable wood, preferably locust or oak, about 1 inch to $1\frac{1}{2}$ inches square on the ends, and about 2 inches more in length than the mortised timber is in thickness.

The corners are planed off, bringing it down to an octagonal shape on the ends, and its sides are then slightly tapered about one-fourth the length, so that the pin will enter the draw bore. If, through carelessness, or error in measurement, the hole in the tenon is not slightly nearer the shoulder than the hole in the mortise, the joint will not be tight, and may result in what is called a *push bore*, which is a term given to this joint when the driving of the pin loosens the pieces instead of tightening them.

78. In braced-frame construction, the mortise and tenon form the joint of nearly every two important timbers that come in contact. In Fig. 12 is shown the corner of a braced-frame building, where *b* is the corner post mortised into the sill *a* at the bottom, and into the plate *h* at the top; the girts, or interties *d*, on one of which the second tier of beams *i* rests, are mortised into the corner post, and secured with a draw-bore pin as above described, while the angle braces *e* are mortised into both the girt and the corner post. The tenons on these beams are cut somewhat differently from those on the other members, owing to the diagonal position of the timbers. At (*b*) is shown an inside view of the corner post and the joints between it and the lower braces. The top of the brace tenon *o* is cut so as to enter the corner-post mortise *p* at right angles to the face of the post; while the bottom of the tenon is in the direction of the plane of the under side of the brace, and the lower side of the mortise is cut on the same plane. The draw-bore hole in the tenon is shown at *q*, but does not show on the inside of the corner-post, as it is unnecessary to bore it all the way through. This constitutes the system of braced-frame construction, and though the studs are sometimes mortised into both sill and intertie, or into intertie and plate, they are thus joined simply to hold them in their places and not to add strength to the general frame. Double studs adjacent to openings, as shown at *k*, should always be mortised, but in modern work the small studs are simply spaced 16 inches on centers, and butt jointed to form a filling between the posts. In braced-frame

construction, where the building is over 30 feet long, it is usually necessary to provide intermediate posts in the side walls connecting the ends of the building in order to have a mortise joint at the end of each horizontal timber.

79. Mortise-and-tenon joints are used almost exclusively in modern work, for the framing of floorbeams around stair wells, chimney breasts, and other openings, as shown in Fig. 32, where *d*, *d* are two heavy floorbeams, called *trimmers*, spaced each on one end of the chimney breast *c*, and connected at *a* by a short piece of joist called a *header*. The beams *b* are called *tail-beams*, and each one is mortised into the header as shown by the ends of the tenons at *f*.

80. Tusk Tenons.—In Fig. 13 (*a*) is shown the tenon *b* on the tail-beam *y* let into the header *w* at its center, and to secure additional strength a tusk *c* is cut on the tail-beam, to rest on the shoulder *d* of the header. The length of the tusk and the thickness of the tenon should each be about one-sixth the depth of the beam.

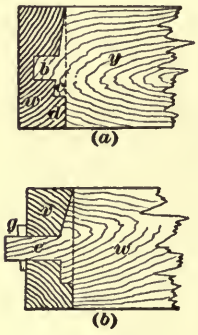


FIG. 13.

At (*b*) the tenon *e* extends entirely through the beam *v*, and is held securely in place by a wooden draw-bore pin, or wedge, as at *g*. This is the form of mortise used to secure the header to the trimmers, while the form shown at (*a*) is used to secure the tail-beams to the headers. Where the joints are made with patent beam-hangers or stirrup irons, no mortising is necessary.

81. Stirrup irons are pieces of wrought iron, generally $\frac{3}{8}$ in. $\times 2\frac{1}{2}$ in., bent to form a hook over the trimmer-beam and a seat in which the header can rest, as shown at *e*, Fig. 32. The trimmer and header are usually nailed together to keep the joint close, while the stirrup iron carries the weight; for good work, however, a strap or bolt should be used to keep the trimmer and header in close contact.

82. Splice Joints.—When timbers cannot be obtained of sufficient length to form an entire sill, plate, or other

horizontal member, it is necessary to resort to some form of a *splice joint*, as shown in Figs. 14 and 15.

Fig. 14 shows a plain splice joint obtained by cutting away one-half of the thickness and width of each timber, *e* and *d*, and then fitting the remaining half of each piece into the space formerly occupied by the half cut away, as indicated by the dotted lines in Fig. 14, where the piece *d* is shown at right angles to the piece *e*, which would be its position in the corner of a building, as shown at *m*, Fig. 12. By turning the piece *d* so that its edges *f g* and *h i* would coincide with the edges *o p* and *n q* of the piece *e*, the joint would splice the two pieces into a continuous timber, as shown at Fig. 15, although when such a condition exists, another form of the joint, known as *beveled* or *oblique splicing*, is considered preferable.

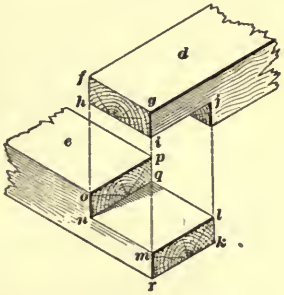


FIG. 14.

This form of splice is effected by cutting away a little more than half the thickness of the timber at *a b c d* and *l m*, Fig. 15, and leaving a little more than half the thickness at the ends *f g* and *j k*. The formation of this joint requires great care, lest the timbers be weakened by cutting too deeply at *a c* and *l m*, but when properly made, this joint does not pull apart as readily as the previous one.

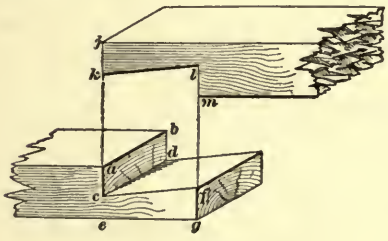


FIG. 15.

83. Dovetail-halving is another form of joint used where prevention from sliding is a desirable condition. Fig. 16 shows two forms of this joint formed as follows: The timber *m* is first halved on the end, in the same manner as the timber *d* in Fig. 14, and the remaining half thickness is then cut to the wedge shape *a b j i*, which is called a **dovetail.** In the timber *n* a *dovetail mortise e f h g l o* is then cut

in, half the thickness of the timber *m*, and the two pieces are then driven together and held in place by spikes or screws.

The form shown at (*a*) is best adapted to positions where timber *m* is intended to be placed at right angles to the

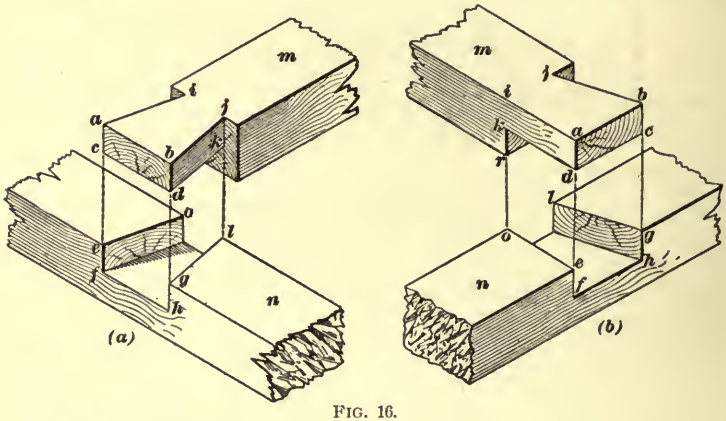


FIG. 16.

timber *n*, and although the form (*b*) is also used in similar locations, it is best adapted to locations where the timber *m* makes an acute or an obtuse angle with the timber *n*, as is shown in Fig. 12, where the timber *n* forms at the same time a tie and a brace to the two timbers *h* forming the plate.

84. A **straddle,** or **bridge, joint,** Fig. 17, is used when a secure footing is required for the toe of a rafter, or strut. The tie-beam *a* is notched on top, to receive the foot of the strut *b*; the side *d e* of the notch is in the direction of and at the same angle as the slant of the strut, while the side *d c* is at right angles to *d e*, and equal in length to the depth of the strut at *f g*. The *bridge tenon h i* is left standing when the notch *c d e* is cut, and a mortise *j k m l* is cut into the end of the strut to straddle it, and thus prevent it from slipping.

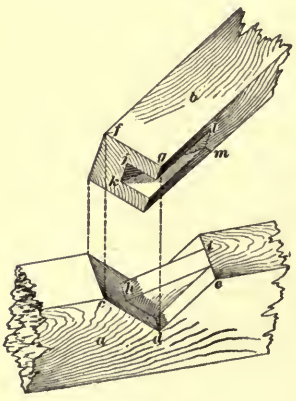


FIG. 17.

Another method of treating this joint is to work the tenon *h i* on the strut timber *b*, Fig. 18, and sink the mortise *j k* into the tie-beam *a*. The tie-beam *a* is then notched on the line *c d*, a distance equal to only half of the depth of the strut *b*, but is still kept at right angles to the direction of the slant of the strut, while the line *d e* has a pitch varying in different cases, according to circumstances.

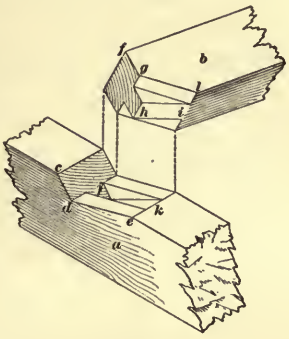
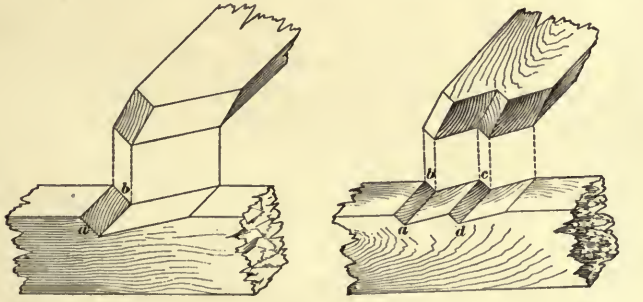


FIG. 18.

85. A method of footing the rafters on tie-beams without the mortise and tenon is shown in Fig. 19 (*a*), where the joint is similar to the one in Fig. 18 in every respect, except that the mortise and tenon are omitted.

Fig. 19 (*b*) shows a variation made use of when the notching of the tie equal to one-third or one-half the depth of the



(*a*) (*b*)

FIG. 19.

strut would weaken the beam too much. Two notches are then made, each of which should be equal to from one-sixth to one-quarter the depth of the strut, so that the sum of the two bearing surfaces *a b* and *d c*, at (*b*), is equal to the single bearing surface *a b*, at (*a*).

86. The various joints thus far considered have been for the purpose of forming a suitable union between two pieces of timber which were in different positions and which served different purposes; and with the exception of the splice joints for sills and plates, shown in Fig. 15, none of these joints could be dispensed with by getting the work out of one piece of timber.

We will now consider such joints as are for the sole purpose of lengthening timbers, in such a manner as will give the most perfect union, with the least amount of loss in strength.

87. Fishing.—A stud or post may be lengthened, or *fished*, as it is called, by the addition of an extra piece of the required length, the ends being cut square and the pieces secured together by nailing on the opposite sides of the stud two pieces of 1-inch board about 2 feet long, as shown at Fig. 20.

FIG. 20.

This is done only in balloon-frame construction, as in braced-frame construction, the distance between the interties and plate, or sill, should never be greater than the available length of studs. But in balloon frames, where the studs are butt jointed against both the sill and the plate without any intermediate joint, the studs frequently require to be fished, especially under the centers of gable roofs, where the height of the house is greatest. Studs can be obtained in all lengths from 13 to 24 feet, and any length in excess of 24 feet can be obtained only by splicing two pieces together.

88. In making a splice joint, attention must be given to the character of the strain to which it will be subjected, whether tension, compression, transverse strain, or torsion, and provision must be made for it to resist that strain, and at the same time to fulfil any other conditions of utility or beauty that may be required of it.

89. One of the simplest form of splice for a tie-beam or other tension member is shown in Fig. 21, where the timber *a* is simply laid against the timber *b* and bolted up with the three bolts shown at *c*. Between the bolt heads, or nuts, and the face of the timber there should be interposed, in each case, a washer *d* to prevent crushing or tearing the surface of the timber when the nut is tightened.

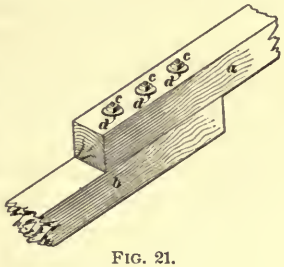


FIG. 21.

This makes a clumsy and awkward looking joint, and should seldom be used, except for temporary structures, but aside from this defect it is excellent for its purpose, and, by reason of the bolts, makes a stronger tension member than would the joint previously described for the splicing of studs, when spikes alone are used to secure the fish-plates.

90. **Scarfing.**—Where the joint is to be subjected to compression or tension, or both, and at the same time must preserve an appearance of neatness and good workmanship, we must resort to what is called *scarfing*, or to fishing with iron plates, or both.

Scarfing consists in the cutting and fitting of the ends of two pieces of timber in such a manner that they will enter into and fit each other so as to form a comparatively secure joint, simply from the conditions of their joining surfaces. They are usually made additionally secure by means of hardwood keys and iron bolts, or screws, but the primary consideration should be, to make the unsecured joint as strong as possible, by means of the proper proportioning of its details and parts.

91. This proportion would vary according to the strains for which the beam was intended, or to which it was likely to be subjected. In Fig. 22 is shown a form of joint which is applicable to a timber which would be submitted to compression, as the two abutting surfaces at *cd* and *ef* are equal to the entire cross-section of the timber, and are at right angles to the line of compression, but under tension

the pieces would immediately pull apart unless secured, as shown, by means of bolts and straps, in which case the entire tensile strain would have to be borne by the straps and the sections of beam immediately under them and between the bolt holes and the end of the beam; and the bolts themselves would be subjected to a shearing strain.

Again, in Fig. 23, we have a joint which, under compressive strains, would be all that is ordinarily required, but if submitted to tension, the entire strain would be borne by the keys *r*, *s* and the iron bolts *m*. It is evident in Fig. 23 that the failing of this joint under a tensile strain would be caused by one or more of the following five conditions: The keys *r*, *s* might shear through and permit the two pieces to slide apart; or, if secured by bolts, the bolts might shear and have the same result. The wood of the beam might split or shear off on some line from *o* to *d e*, allowing the pieces to pull apart without disturbing the keys; or, the beam might part under the tension at the thinnest point, as at *b*; or, the bolts might remain intact, but the material between them and the end of the beam might be sheared off and permit the beams to separate.

92. It is evident, therefore, that in order to secure the greatest tensile strength combined with the most economical distribution of material, the following conditions must exist in any scarf joint, no matter what its form may be:

The sections of the timber subjected to a shearing strain must be so proportioned that their shearing value will be equal to the portions of the timber subjected to a tensile strain; and if the joint is additionally secured by means of iron bolts or plates, or both, the combined tensile strength of all the members submitted to tension must be equal to the combined strength of the members submitted to shear.

For example, if we use a joint of the form shown in Fig. 23 for a beam subjected to tensile strain, and omit the four bolts *m*, we must proportion the parts so that the shearing strength of the keys *r*, *s*, and the shearing strength of the material between *o* and *d e* or between *p* and *i j* will equal the tensile strength of the section at *b*. For, no matter how much

stronger any one of these details may be than is required of it, the beam will not acquire additional strength thereby, as it will only be as strong as its weakest part.

The importance of analyzing the conditions under which a beam will be strained is, therefore, very evident, and it is the comprehension of these conditions, and the knowledge of how to provide for them, that enables us to select a proper form of scarf joint in each particular case.

93. Fig. 22 shows the simplest form of a *scarf joint*. The timber *a* is cut half through its depth, on the line *c d*, which is perpendicular to the adjoining face of the timber, as is also the line *c g*. The timber *b* is similarly cut half its depth on the line *e f*. The material between these cuts and the end of the timber is then removed to the line *d e*, and the two pieces *a* and *b* are then joined in the same manner as the splice joints in Figs. 14 and 15, and are securely bolted. Thus far the joint presents the same mechanical features under tension as would the joint shown in Fig. 21; but when subjected to compression the timbers *a* and *b* have a flat bearing on the surfaces in contact at *g c d* and at *e f*, which, combined, are equal to the entire bearing surface of the end of the timber, each surface being the full breadth by half the depth. The weakness of the joint under compression arises, therefore, from its tendency to bend and fail, either through the parting of the bolts, or from the breaking of one of the laps near the lines *e i* or *d h*. This weakness can be compensated, however, by bolting to the top and bottom of the timber an iron plate or bar *j k*, whose length is equal to twice the length of the joint *d e*, with a breadth equal to one-third of the breadth of the beam, and a thickness proportioned according to the strain it is likely to be subjected to. These iron bars

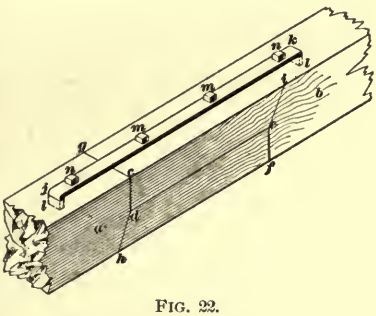


FIG. 22.

are usually turned over on the ends, as shown at *l*, and let into the top of the timber. The two bolts *n* merely hold the ends in place, while the bolts *m* pass through both the bars and the laps of the joint.

The iron bar prevents the timber from bending in the direction of its depth, and the bolts *m* and the bearing surfaces *g c d* and *e f* prevent it from bending in the direction of its breadth under compression, while the bolts *m*, combined with the bars *j k*, and the turned-in ends, or lugs *l*, prevent the joint from parting under tension. This joint is not adaptable to a tensile strain, however, as its strength would depend entirely on the shearing value of the bolts *m* and *l*, and the tension of the bar *j k*. Nor is it fit for a transverse strain, which might bend the iron bar and tear out the bolts.

94. If the timber shrinks after the scarfing is complete and the beam is in place, this joint will work loose and cause trouble unless it is carefully watched and the bolts are tightened up from time to time, until the wood is thoroughly dried out and the shrinkage ceases.

The proper length of the joint on the line *d e* varies with the material and the circumstances, as will be explained further on.

95. In Fig. 23 is shown another form of this joint, where the combined bearing surfaces of the two pieces *a* and *b* is still equal to the sectional area of the timber, and the tendency to bend in the direction of the depth is lessened by the form of the scarfed ends of the joint without the use of an iron plate or bar; the joint, however, is not adapted to a transverse strain, as the parts are cut away too

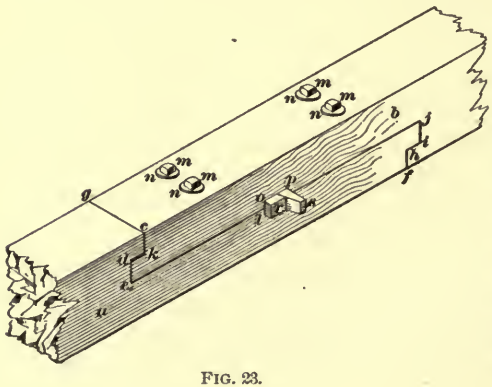


FIG. 23.

much. The timbers *a* and *b* are first sawed half through their depth and prepared in the same manner as for the joint in Fig. 22, but from the top of the lap, and at a distance from the end of the timber equal to half the thickness of the lap, the timber is again sawed through, until the line *c k*, on timber *b*, is equal to one-quarter the depth of the entire timber, or one-half the depth of the lap. The material between *c k* and the end of the lap is then removed, and on the shoulders of timbers *a* and *b*, half way between the surface and the projecting lap, the timber is sawed through in the direction of its length a distance *k d*, on timber *a*, equal to one-half the thickness of the lap. The material between *k e* and the face of the shoulder is then removed with a chisel, care being taken to keep the surfaces parallel and true throughout the thickness of the timber. The pieces *a* and *b* are then fitted nicely together in the position shown in Fig. 23, and at the middle of the line of the joint *e j* is marked the position of the rectangular hole *l o p*, the depth *l o* being equal to about one-sixth the depth of the timber, and the length of the hole *o p* being twice the depth *l o*. The timbers are then separated and half the hole *l o p* is cut in each piece separately, and the distance from *o* to *e*, on timber *b*, is made $\frac{1}{16}$ to $\frac{1}{8}$ of an inch greater than the distance *l e* on timber *a*. When the pieces are finally put together, a pair of wedge-shaped keys *r s* are driven into the hole, thereby forcing all the bearing surfaces into close contact. Holes are then bored through the depth of the timbers and four bolts *m* are inserted and screwed up tight against the circular washers *n*.

96. The advantage of this joint over that shown in Fig. 22, is that it is not so seriously affected by shrinkage, and at the same time preserves the most favorable feature of a beam under compression—that of a full bearing surface, equal to the cross-section of the beam. Should the two pieces composing the joint shown in Fig. 23 shrink to any considerable extent, the only result would be the loosening of the bolts *m*, unless the keys *r* and *s* were made of some

harder wood than the beams themselves, and, therefore, did not shrink as much in proportion. This would cause the joint to open slightly at the middle part of the line *e j*, but it could be prevented by making the keys about $\frac{1}{16}$ inch less in thickness than the hole at *l o*. Shrinkage would then not affect the appearance of the joint at all, and the bolts could be tightened from time to time, as in the previous case; the joints being thus maintained close and secure at all times.

This joint is better adapted to resist compression than tension, as under tension the entire strain would come upon the bolts *m* and the keys *r*, *s*. Great care should therefore be exercised when this joint is to be submitted to tensile strains, to see that the bolts fit the holes tightly, and that the keys are well driven, otherwise, under alternate compression and tension, the joint is liable to work loose. The projecting ends of the pieces at *d c* and *j i* serve only to keep the top of the joint flush.

97. The joint shown in Fig. 24 is similar in construction to that in Fig. 23, except that the line *d c* is carried through the timber in a slanting direction instead of parallel to the top and bottom, and is not continuous in each timber; that is, the line of juncture on timber *a* extends from *d* to *l* and then makes a break *l o* at right angles to *d l* and then proceeds from *o* to *e* at the same angle it started. The extent of this slant from the surface of the timber depends upon the length of the joint, as the cuts *d c* and *e f* should never be less than one-sixth the depth of the timber when at right angles to *d e*, and when the angle *c d l* is less than 90 degrees the distance *c d* should be increased.

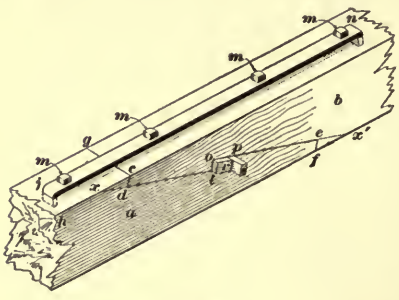


FIG. 24.

98. This style of joint is not as strong as that in Fig. 23 when subjected to compression, but is somewhat stronger

under tensile strain, as part of the stress is taken up by the iron bar *j n*, which is applied in the same manner as in Fig. 22. It is well adapted to a transverse strain, however, and when so intended, slight modification should be made, according to circumstances. When a beam is submitted to a transverse strain, its top is in compression and its under side is in tension; therefore, a combination of two forms of joint should be made to suit the two conditions. When the joint shown in Fig. 24 is used as a beam with a transverse strain, it is better to let the line *c d* run at right angles to the top of the beam and extend half way through, as the line *c d* in Fig. 22. This adapts the upper half to a compressive strain, while the under side may be scarfed, as *o e f* in Fig. 24, and have an iron bar or plate on the bottom.

The rectangular hole, or keyway, *l o p* has its long side on the cuts *o e* and *d l*, and the keys *r* and *s* have each a full bearing surface on one timber instead of a half bearing on each timber, as the keys in Fig. 23. Under compression, however, there is a tendency for the joint to slide on the line *d e* and split off the small bearing triangles *c d x* and *f e x'*. The iron bar could hardly be expected to prevent this, as it would probably bend away from the timber between the bolts, and a square butt end, as above described, should, in such a case, be used. In this joint the keys *r*, *s* must be driven with caution, as the least overdriving would tend to split the timber on the line *d x* or *e x'*.

99. Shrinkage in the material in this joint would first cause it to open slightly on the line *d e*; then, if the timber were under compression, this would be compensated by the sliding of the two pieces into close contact again, and the consequent loosening of the keys *r*, *s*; but if the timber were subjected to a tensile strain, the joint would remain open on the line *d e* until the keys *r* and *s* were driven tighter to close the joint, and the bolts *m* were tightened to hold it in place after the shrinkage had been taken up.

100. Fig. 25 is a modification of Fig. 24, in having the line *d e* continuous and passing it through the center of the

keyway *r s*, and also in having the meeting line of the two timbers cut at an obtuse angle *c h g*. This renders the beam much more reliable under a cross-strain tending to bend it in the direction of its width, and the pointed toe also tends to keep the timbers flush. Like Fig. 24, this joint is better suited to a tensile than compressive strain, but its behavior after shrinkage is more like that shown in Fig. 23. If used in a position where it will be subjected to a transverse strain, it should have the upper half prepared as described in Art. **98.**

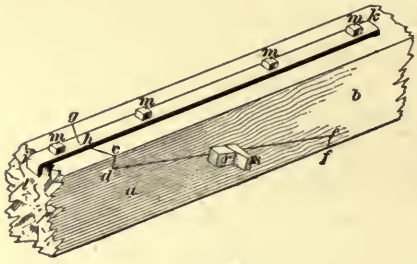


FIG. 25.

101. A method of lengthening timber and preserving a considerable degree of strength, both for longitudinal and for transverse strains, is shown in Fig. 26. Three thicknesses *a*, *b*, and *c* of the same size of timber are bolted together with four bolts *m*, the joints *f g* and *h d e* being squarely sawed and tightly butted, in order to secure a good bearing. The bolts must fit the holes exactly, and the nuts on their ends must be screwed as tight as possible, as upon the bolts depends the entire strength of the joint.

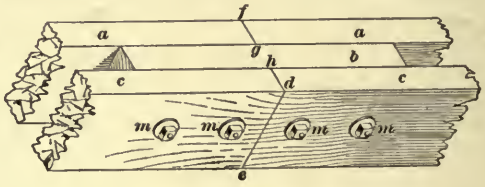


FIG. 26.

102. In proportioning these scarf and lap joints, in oak, ash, elm, or hard pine, the whole length of the joint should be about six times the depth of the timber, when no bolts or plates are used, and the permanence of the union of the pieces depends upon the keys alone; but when bolts are used, the length of the joint should be about three times the depth of the beam, and when both means are adopted, or iron plates are interposed between the bolt heads and the

timber, the joint can be as short as twice the depth of the beam. With pine and similar soft woods the length of the scarf should be twelve times the depth of the timber when there are no bolts to sustain the piece, and when reinforced by bolts, six times the depth; or with bolts and plates, a length of four times the depth of the timber is considered sufficient.

103. In Fig. 27 is shown a form of joint more suitable for a short post than either of the foregoing scarfed joints, but it is unfitted for tensile strain. The ends of the timbers *a* and *b* are carefully squared on the line *c d e*, and in the center of the end of each piece is bored a hole to take the stud bolt, shown dotted at *f g*; at a distance from the end of each, and not less than two-thirds the thickness of the post, a square hole *h* is cut where the nut for the bolt is inserted, and through which it is screwed tight upon each end of the stud bolt. This brings both ends of the post into close contact, so that there will not be any perceptible compression at this point when the working load is imposed.

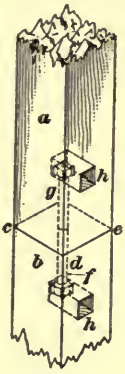


FIG. 27.

104. In Fig. 28 is a cheaper form of joint for a similar purpose, though this may also be used in positions where it will occasionally be subjected to slight tensile strain. It is an improved form of that shown in Fig. 20, but with *indents* cut at *d e f*, in order that any tensile strain will come upon the wooden fish-plates, or battens *c*, and the lugs of the timbers, and not entirely upon the nails, or spikes, as is the case in Fig. 20. The thickness of the plates *c* should each be equal to not less than one-quarter the depth of the timbers *a* and *b*, and the indents *d e f* should be not more than one-third the thickness of the fish-plates. The entire length of the joint from *d* to *d'* may be three times the timber depth, and the length of the indent from *f* to *d* about one-quarter the

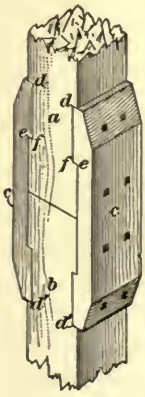


FIG. 28.

length of the joint. The fish-plates may then be bolted through the timber from side to side with four bolts, or may be spiked to each side with from eight to twelve spikes, as shown.

105. In Fig. 29 the fish-plates are replaced by iron straps *c* not less in breadth than one-sixth the thickness of the timber, and sunk into the face of the wood a depth equal to their thickness, as shown at *e*. Holes are bored or punched in these straps to receive the lagscrews, or spikes, which serve to bind the timbers and straps together, and the iron, or hardwood dowel *d*, in the center of the posts, serves to keep the two pieces in alinement. This joint is suited only for compressive strains, and with Figs. 27 and 28, should be used only in a perpendicular position, unless the joint itself is independently supported.

FIG. 29.

This completes the description of some of the joints most commonly used in the framing of buildings, and we will now proceed to the details of general framing.

FRAMING.

SILLS, POSTS, AND STUDS.

106. The carpenter's work in a frame building usually commences when the foundation is completed. First, a timber, called the *sill* (see *a*, Fig. 12), is laid upon the top of the foundation wall to receive the superstructure of wood. This sill varies from 6 in. × 8 in. to 8 in. × 10 in. in regular framed buildings; and from 4 in. × 6 in. to 4 in. × 8 in. in balloon-framed buildings, and is laid about 1 inch from the outer face of the foundation wall. The corners of the sill are *halved*, as shown in Fig. 14, and when necessary to splice it in order to cover a longer run of wall than can be

accomplished by one piece of timber, the *beveled-splicing* joint, shown in Fig. 15, is usually adopted.

The corner posts are then erected at the angles of the building, as shown at *b*, Fig. 12, and are usually composed of from 6″×8″ to 8″×10″ timbers in regular frames and of from 4″×6″ to 6″×10″ timbers in balloon frames. The lower end of the corner post is generally mortised into the sill at the halved corner and its upper end is mortised to the plate *h*, Fig. 12, although in balloon-framed work the plate is sometimes merely spiked to the end of the corner posts, the internal angle being formed by spiking a stud to the face of the corner post.

107. The studs *k*, Fig. 12, are sometimes mortised into the sill *a*, into the girt, or intertie *d*, and into the plate *h*, although in modern work they are more frequently simply butt jointed in position, except in the case of double studs at the sides of openings; while in balloon-framed work they should always extend from the sill to the plate in one piece, if possible, or be spliced in the manner shown in Fig. 20, where the height is too great. To carry the floorbeams in the second or third story, a *ledger board*, or *ribbon*, shown at *k*, in Fig. 72, is notched into the studs, each beam being spiked to the adjacent stud. In regular frames the upper floorbeams rest upon the intertie, as shown at *i*, in Fig. 12.

FLOORS.

108. **Floorbeams** are *sized* or notched on the sill, as shown in Fig. 30, in order to bring their tops to an even line, any variation in the depth of the beams *b* being removed with the notch at *c d*, so that all the beams are exactly the same depth from *a* to *c*, thus securing an alinement of their upper edges. Nearly all timbers will curl or warp more or less in drying out, or seasoning, and when floorbeams are laid they should be placed with this convex, or *crowning*, side upwards, in order that any deflection of the beam due to the

superimposed weight will bring the floor to a level line rather than produce a sag or dip in the middle of its span.

In the second story of a building the beams are notched over the interties, or girts, in the same manner as over the sill, and in balloon frames, where the girt may be but an inch in thickness, the floorbeams are cut on the under side, forming a channel, or groove, across the beam which rests on the girt, and not only brings the tops of the beams to a level, but also forms a tie across the building. In brick or stone walls, the beams are maintained at the same level by

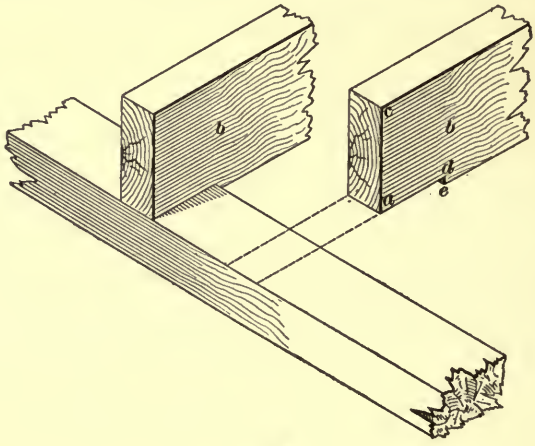


FIG. 30.

placing small pieces of slate under the shallower beams, and thus raising them to the proper level. Thin slips of wood are sometimes used instead of slate, but as they are seldom made of a uniform thickness, and squeeze readily under pressure, they are not to be recommended. The method of tying such beams into a brick wall is shown at *k*, Fig. 32, where a strip of iron not less than $\frac{3}{8}$ in. $\times 1\frac{1}{2}$ in. in section, called an *anchor*, is nailed to the side of the beam, and its end, which is bent around a $\frac{3}{8}$-inch iron rod, is allowed to project from 4 inches to 8 inches beyond the end of the beam, and the brick or stone work is then carried up around it, enclosing the anchor and securing the beam.

109. Bridging is the term given to a system of bracing applied between floorbeams in order to prevent them from bending sidewise, or curling out of position after they are in place. They also tend to strengthen the floor system when it is not uniformly loaded, by distributing the weight among the adjacent joists. Fig. 31 shows a method by which this is accomplished, called *herring-bone* bridging, in distinction from other forms of bridging to be described subsequently. The herring-bone bridging shown in Fig. 31, is generally formed of $2'' \times 4''$ pieces *a* and *b* cut between, and well nailed to, the joists *c*, as shown, and spaced in rows about 8 feet apart.

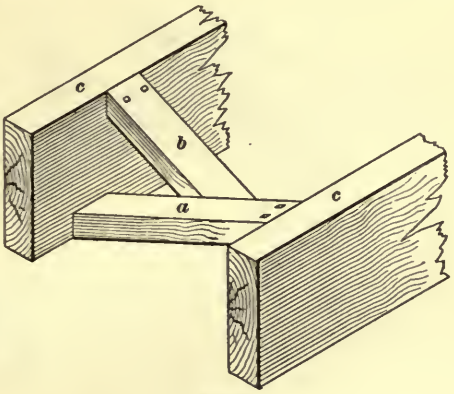


FIG. 31.

110. Trimmer Beams.—Where a chimney occurs in the side wall or in the center of a building, it is necessary to *frame* the floorbeams in such a manner that no wooden beam shall come within 4 inches of the brickwork enclosing a chimney flue. This is accomplished as shown in Fig. 32, the method of framing and the joints required having been already described. When there is to be a fireplace opening and hearth in front of the chimney, the header *a*, Fig. 32, should be placed from 1 ft. 9 in. to 2 ft. 6 in. away from the chimney breast, in order to provide room for a trimmer arch, as shown at *a*, in Fig. 80.

This method of framing with *headers*, *trimmers*, and *tail-beams* is also used around the openings for stairs, skylights, dormers, and dumb-waiter shafts. In all cases the header *a* and the trimmers *d*, Fig. 32, are made at least twice, or three times the thickness of the regular floorbeams *b* and *k*,

as upon these trimmers is imposed the combined load of all the tail-beams *b*.

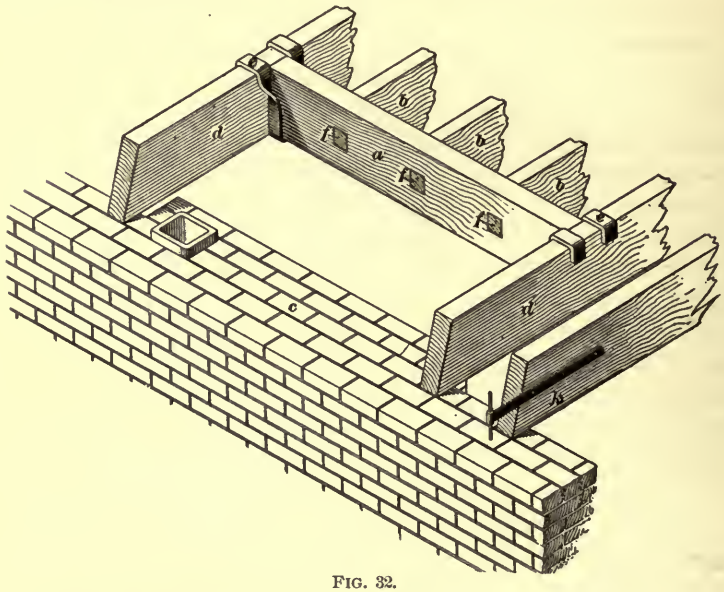


FIG. 32.

111. Flooring is applied directly to the top of the joists, after they have been brought to a true alinement, as above described, and is *plain* or *matched*, *single* or *double*, as the case and character of the building requires.

A plain floor consists simply of second quality boards nailed directly to the floorbeams, each plank being from 6 in. to 10 in. in breadth, and forming a butt joint with its neighbor. Such a primitive floor is seldom used except in temporary structures.

A matched floor is laid with selected material which has been *matched*, or *tongued and grooved*, as shown in Fig. 33. This matching, though formerly worked entirely by hand, can now be done by machinery at the mill where the material is cut up from the seasoned timber, and matched flooring is a commercial article purchasable at any lumber yard.

112. Matched floor boards, when laid, are about $\frac{3}{8}$ of an inch narrower than the width at which they are purchased,

which shortage represents the amount cut away in the milling. At *a*, *b*, and *c*, Fig. 33, are shown three pieces of matched 4-inch flooring, which measures, when laid, but $3\frac{5}{8}$ inches as shown, but the tongue *d* projects $\frac{1}{4}$ inch, making the total width of the board $3\frac{7}{8}$ inches, the remaining $\frac{1}{8}$ inch being lost partly in waste in the process of matching, and partly by shrinkage after the matching has been done. At one edge of the board a projecting rib *d*, called the *tongue*, is cut, and on the opposite side a groove *e* is sunk a trifle deeper than the projection of the tongue. The upper edge *f* of the groove projects about $\frac{1}{32}$ inch more than the lower edge, so that when the flooring is laid and the groove is driven tight on to the tongue, as at *l*, the $\frac{1}{32}$-inch clearance between the front of the tongue and the bottom of the groove at *m*, and between the shoulder of the tongue and the lower edge of the groove at *n*, leaves the upper edge of the groove to be driven tight against the upper shoulder of the tongue, thereby forming a tight joint on the surface, as shown at *p*.

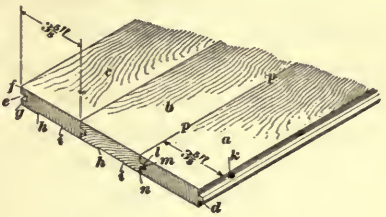


FIG. 33.

The same result is obtained by keeping the under shoulder of the tongue slack, in which case the grooved edge would be square. The tongue is always placed slightly below the center of the thickness, so as to give more wearing surface to the floor and render the edge of the groove less likely to curl up.

When this matched flooring is of hardwood, such as oak, maple, or yellow pine, a shallow groove about $\frac{1}{32}$ inch deep is cut along the under side, as shown on pieces *b* and *c* at *h i*. This enables the boards to be laid tight to the beams or under flooring, and causes them to be less affected by any slight unevenness of the substructure.

113. Matched flooring should always be *blind nailed;* that is, the nails should be driven in the upper angle of the tongue, as shown at *k*, in a diagonal direction, and, in the

hardwoods, the nails should be punched in, so that their heads are well below the surface, and as the groove of the next piece covers the tongue, it hides them from sight. The boards are nailed only on the tongue edge, as the groove edge is held fast by the tongue. Next the wall, on both sides of the room, it is necessary to nail the first and last board through the upper face. As the baseboard will cover these nails the entire floor will present an even surface, without a nail head in sight.

This description of flooring would more often apply in the case of a double floor, though a first-class job of a single matched floor would demand equal care.

114. A *double floor* consists of a rough, plain, or matched floor of boards (preferably matched), laid when all the beams are in place and bridged, and of a second, or finished floor, of the character just described in detail, laid when all the rough work in the building is complete, and when the joiner work is in progress. In first-class work, the finished floor should not be laid until the base, window and door trim, etc., have been fixed in place.

Over the rough floor of a building, all the coarse work is carried on, such as lathing, plastering, and the first coats of painting.

115. When two thicknesses of flooring are laid, the first, or under floor, is usually laid diagonally across the beams, as shown at *a*, Fig. 34, and the second, or finished floor, is laid on top of this, but at right angles to the beams, as shown at *b*. When the rough floor is laid at right angles to the beams, and the finished floor runs in the same direction on top of it, the shrinking of the wide boards

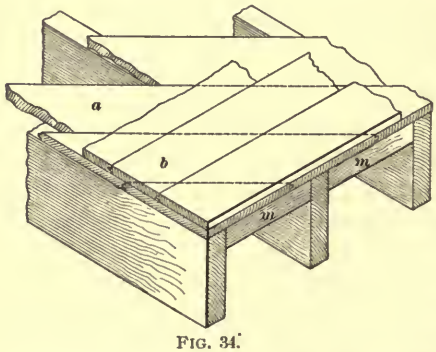


FIG. 34.

beneath may pull two or three of the boards of the finished floor up tightly together, thereby leaving open joints in the upper floor at regular intervals, corresponding very nearly with the widths of the rough boards below. The diagonal laying of the lower flooring obviates this difficulty, and to insure an even bearing all around, it is sometimes necessary to nail between the beams, at their ends, some supporting pieces *m*, *m*, Fig. 34, to which the diagonal boards may be spiked. The rough floor should be well nailed to the joists, and care should be taken that the finished floor is nailed only over the joists; when driven into the boards the nails possess little value, and are likely to work loose. For floors $\frac{7}{8}$ inch thick, $2\frac{1}{2}$-inch cut nails should be used, and for $1\frac{1}{8}$-inch floors, 3-inch nails.

The thickness of the boards in the lower and upper layers of a double floor are usually 1 inch and $\frac{7}{8}$ inch, respectively, but single floors in dwellings should have the boards at least $1\frac{1}{8}$ inches thick. In mills, factories, warehouses, etc., the flooring varies from $1\frac{1}{8}$ to 4 inches in thickness, as will be explained further on.

PARTITIONS.

116. Partitions are constructed of pieces of timber from 2 in. × 4 in. to 3 in. × 6 in. in section, called **studs**, which are set vertically, with the depth of the stud in the direction of the thickness of the partition, and are spaced 12 inches or 16 inches on centers, in order to accommodate the 4-foot lengths of lath which they are to carry. Any difference that may be required in spacing should be made at one end of the room, or, where the irregularity of spacing is caused by the insertion of a door or window, the difference should be made entirely on one side of the opening. Every spacing of studs which is a variation of the above will cause the laths to project past, or fall short of, the desired nailing point for their ends, necessitating in either case the cutting of the lath at the center of the nearest stud, thereby causing an expenditure of time and a waste of material.

117. Where partitions are required in a direction across the floorbeams, as shown in Fig. 35, a sill *a* is first laid on the beams and perpendicularly over it, and on the under side of the ceiling beams is nailed a *cap*, shown at *b*, Fig. 36; between this sill and cap the studs are set and securely toe-nailed through each end.

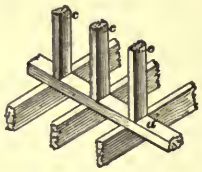


FIG. 35.

118. In Fig. 37 is shown a method of securing a firm internal angle at the corner of a building. *a* is the corner post of a building resting upon the sill *s*, and *b'*, *b*, *b* are the studs of the outside wall. The corner post in this case is made with a $4'' \times 6''$ piece *a*, and a $2'' \times 4''$ stud *b'* spiked to it flush with the outside. This arrangement leaves the two surfaces *c* and *c*, to which the ends of the lath of each wall may be securely nailed.

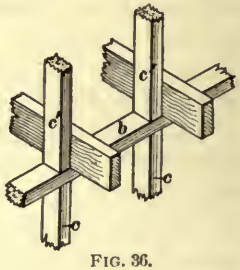


FIG. 36.

119. In Fig. 38 is shown a method of forming the interior angles where partitions are placed at right angles

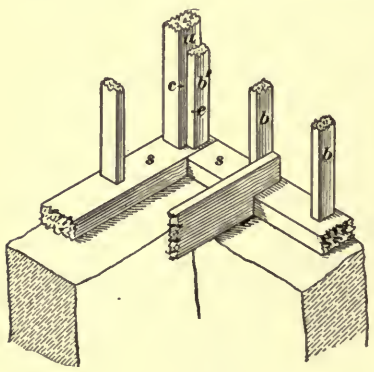


FIG. 37.

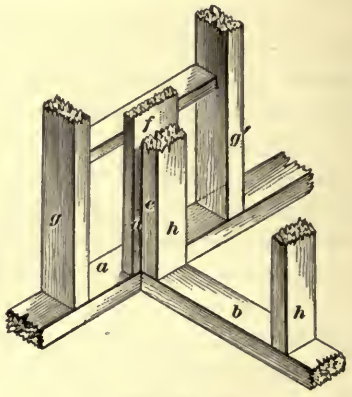


FIG. 38.

to each other; *g*, *g'* are two studs, which may also be in the

outside wall of a building, and *h*, *h* are the studs of an interior partition. At *f* on the partition, or wall, is a piece of plank 1 inch thick and 2 inches wider than the stud *h* to which it is nailed, and extending from the sill *a* to the top of the partition, thus affording a surface on each partition where the lath ends may be nailed, as at *d* and *e*. A strip may with advantage be nailed on top of the sill, to which the plank *f* can be nailed.

120. When the partition of an upper story comes vertically over one in the story below, the studs of the upper one should be set upon the cap of the one below, as shown at *c'*, Fig. 36, and not upon the beams, as in Fig. 35.

This reduces the effects caused by the shrinkage of the timbers, which is bound to occur as the building dries out, and the fewer transverse thicknesses we have as supporting members to partitions, etc., the less will be the shrinkage and ultimate settlement of the whole house.

When a partition runs parallel with the beams it should stand on a beam framed in especially to receive it, or it should rest on the cap of the partition below, if such a partition exists.

121. All important partitions should be well supported at their foundations, either by a brick wall or by a girder carried upon brick piers or wooden posts, with masonry footings. This girder should be very little deeper than the sill of the house, or, when extra depth is demanded by the degree of strength required, the ends of the beams may be notched over the edge of the girder in somewhat the same manner as the floorbeams are notched over the sill in Fig. 30. In this way the amount of shrinkable material between the top of the post and the bottom of the partition studs may be reduced to very nearly the same as it would be in the sill under the outside walls; or, if the girder cannot be notched sufficiently to effect this, the house sill may be made somewhat thicker, or the floorbeams must be set with their interior ends slightly raised, so that subsequent shrinkage of the girder will render

them level. It is shrinkage of material that causes new houses to settle, and if the settlement is uniform, no harm results from it, but irregular settlement causes uneven floors, cracked plaster, and doors and windows that refuse to open readily or close tightly.

Good, sound, well dried material, therefore, should always be used, when such is obtainable, and all unsound, curved, knotty, or shaky timber should be rejected as unfit for any purpose except firewood.

122. Lathing is applied to the partitions as soon after the studs are in place as is convenient. Where pipes or wires are to be carried within the walls, it is sometimes necessary to delay at least a portion of the lathing until they are in place; or, when the exact location of these interior lines is determined upon, the lath may be left off one side of the partition until the wiring or pipe lines have been inserted.

Laths consist of strips of soft wood, generally $1\frac{1}{2}$ inches wide, $\frac{1}{4}$ inch thick, and 48 inches long; they are laid horizontally on the partitions, nailed to each stud, and maintained, as nearly as possible, at a uniform distance apart—usually from $\frac{1}{4}$ to $\frac{3}{8}$ inch, as shown at *g*, in Fig. 43.

To guard against unsightly cracks in the plaster at the angles of the rooms, suitable nailing strips, as *d* and *e*, Fig. 38, or double studs, as *a* and *b'*, Fig. 37, must always be provided; and *under no circumstances* must the lath be permitted to extend across from one stud to another behind the end of a partition, as from *g* to *g'*, Fig. 38.

123. Plaster Grounds.—Where any woodwork is to be applied against a plastered wall, such as a baseboard, chair rail, wainscot, picture molding, etc., it is always necessary to provide a proper bearing to nail it against, in order to avoid cracked plaster and insecure fastening, which would result from nailing through to the lath and plaster into the stud. Therefore, a **ground,** or nailing strip *a*, Fig. 73, is nailed against the studding at such a height as the top of the base,

or other trim, will reach, and of a thickness equal to that of the lath and plaster. To this *ground* the trim is fastened when the plastering is finished and dry. When the trim to be applied is in the form of a wainscot or other wide surface, it is sometimes necessary to have several grounds at different heights, to which the separate pieces may be attached. It is always desirable in first-class work to have the walls lathed below the grounds, even down to the floor line, and also plastered to that point, as the back of the trim is thereby protected from exterior dampness and drafts, and vermin have less opportunity to make passages behind the walls.

124. Though the primary purpose of grounds is to form suitable nailing places for interior trim, they, at the same time, exercise another and most important function—that of forming a stop for the plaster. If no grounds are provided, and the plaster is simply carried to some arbitrary point which will be hidden behind the trim, we have an insecure job, the edges of which are liable to break off and crack as the trim is put in place, thereby necessitating patching and repairing after the job is complete; but if a ground is placed at every side where the plaster will stop, the entire wall surface is enclosed in a frame, and is secure from damage.

125. When lathing is applied to the ceiling of a room, it is sometimes nailed directly to the under side of the ceiling beams, though in first-class jobs it is always best to provide some means of bringing the bottoms of the ceiling beams to a level alinement before the lath is nailed on.

126. Cross-Furring.—In Art. **108** is explained the method employed to bring the top of all the floorbeams into alinement, and, as will be readily seen, any irregularity in the depths of the beams will, by this method, be thrown to the under side. Therefore, when the under side of these beams is to carry a plastered ceiling, they must first be leveled by a system of *cross-furring*. This is accomplished by nailing thereon furring strips 1 inch thick by 2 inches

wide, and spacing them 12 inches on centers. These furring strips are either notched over the beams or dropped below them by the insertion of slips to bring them in line.

On these furring strips the laths are then nailed, and if, on any side of the room, there is no beam in the angle between the side wall and the ceiling to which a furring strip can be nailed to secure a firm corner, pieces must be nailed on the plate of the partition to receive the ends of the strips, in the same manner as nailing places were established at *e c* and *e d*, in Figs. 37 and 38, to receive the ends of the lath. When a ceiling is cross-furred, it is more rigid; the plaster is less liable to crack by the vibration of the floor-beams, and, being generally of less width than the thickness of the joists, a better rivet is secured for the plaster.

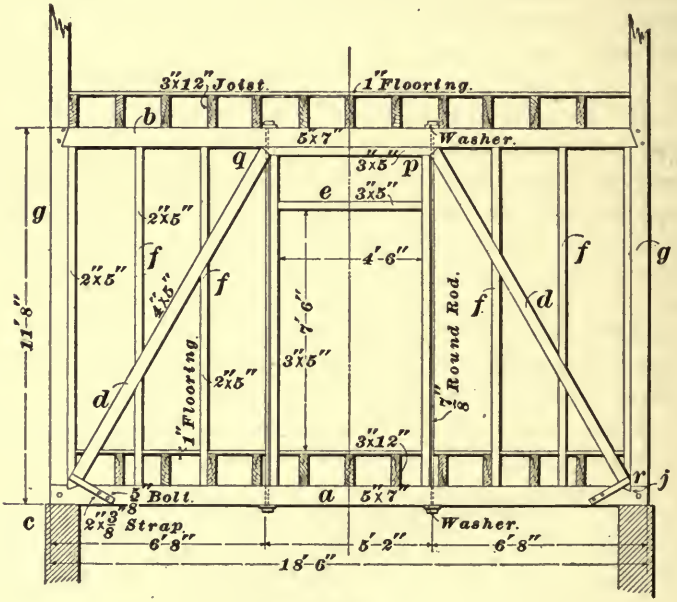


FIG. 39.

127. Trussed partitions are sometimes necessary where there is no supporting partition in the story below, or where a partition has a number of doors or other openings through

it so weakening it that it cannot safely carry the required weight to be imposed upon it. Fig. 39 shows a trussed partition with a door 4 ft. 6 in. × 7 ft. 6 in. in the center of it. The sill *a* and the plate *b* are made 5 in. × 7 in. The studs *c* at each side of the door are 3 in. × 5 in., and the upright wall members *g* are 6 in. × 5 in. The height of the door is limited by the 3″ × 5″ timber *e*, from the ends of which the 4″ × 5″ braces *d* extend to the ends of the sill *a*, where they are *let in* at *j*, to secure them from slipping. A truss *c q p r* is thereby framed, around the members of which the 2″ × 5″ studs *f* are cut. The entire weight of this partition, together with any superimposed load, will come upon the points *c* and *r*, where ample support must be provided to carry the weight down to a proper foundation.

128. In Fig. 40 we have a partition with three openings, the essential difference between it and that shown in Fig. 39

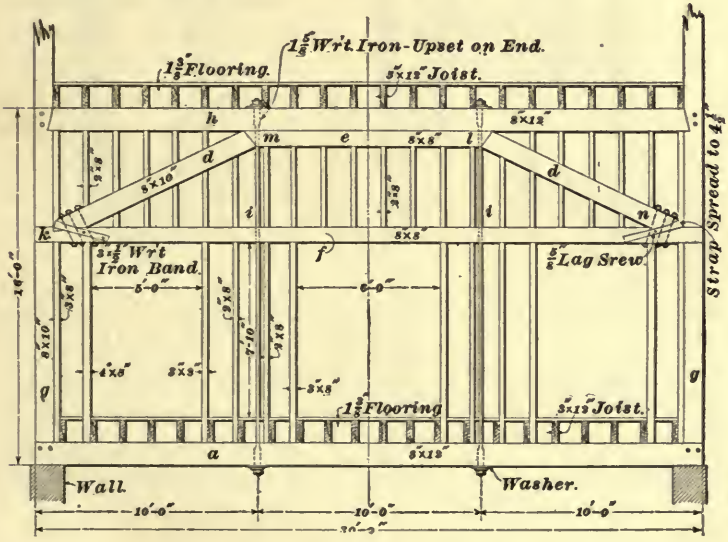


FIG. 40.

being that the truss is entirely above the openings, while in the former example the opening was through the center of the truss. In Fig. 40 we have the sill *a*, into which are

mortised the wall members *g*. The tie-beam *f* marks the top of the openings, and into it the rafters, or struts, *d* are notched at each end, with the compression member *e* between their tops. This entire truss *k m l n* is carried by the wall posts *g*, and the weight of the door posts and the studs between them is carried to the top of the truss through the tie-rods *i*, which pass, also, through the plate *h*; the weight of the entire partition is therefore carried by the corner, or wall posts *g*, which, in turn, must be well supported from below.

129. Door and window openings more than 3 feet wide, should have their heads trussed, as in Fig. 41, the tie-beam *c* resting upon the studs *d*, and the struts *e* footed into the tie-beam. This prevents the top of the door from sagging in the center, as the superimposed load is all carried to the side studs *d*.

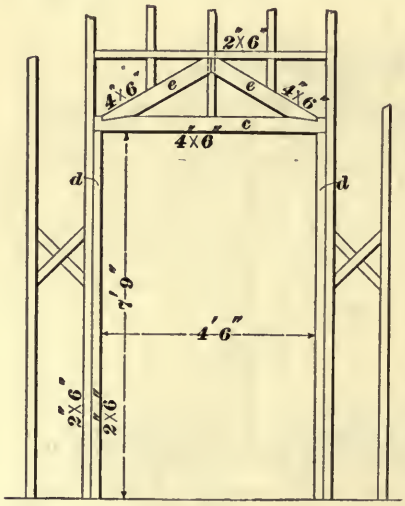


FIG. 41.

Double studs, or larger sized studs, should, therefore, always form the sides of door and window openings, as shown at *d*, Figs. 41, 42, and 43, for the purpose of gaining strength and also to afford a nailing place for the trim. When a single piece of timber of the proper size for this is not at hand, it is customary to spike together two pieces of the ordinary studding and use them as a double stud, as shown at *d*, Fig. 42.

130. The sizes of doors and windows as marked on plans or working drawings are the dimensions of the finished parts, and in framing the openings for them in the studding, an allowance must be made for windows of about 5 inches

in height and 7 inches in width, where there are weights; but if the window is to be hung without weights, an allowance of 3 inches at the sides will be sufficient.

In door openings, false jambs are generally inserted, as shown at *c*, Fig. 43. These are nailed to the studs, and the plaster finished to them, in order to make the sides of the opening perfectly vertical and the top level; therefore, an

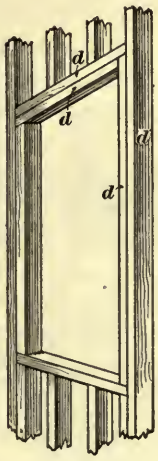


FIG. 42.

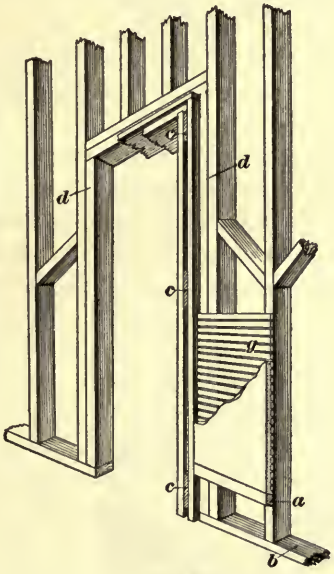


FIG. 43.

allowance of about 5 inches in width, and 3 inches in height is required in framing the stud openings for doors, and an ordinary door, 2 ft. 10 in. × 7 ft., would require a framed opening 3 ft. 3 in. × 7 ft. 3 in. When setting the finished jamb, solid blocks should be placed where the hinges of the door will come, as shown in Fig. 43.

THE FRAMING OF ROOFS.

131. A *roof* may contribute much to the elegance and completeness of any building, as, by its fitness and appropriateness of outline, and its harmony with the structure, it

crowns the whole. The angle to which any roof may be built, is variously designated as the pitch, slope, or inclination. There is, in practice, a rule for calculating a roof pitch by the proportion of its span to its height; however, the most simple and practical way of treating this pitch is by calculating the rise, or vertical height, in proportion to the foot of horizontal run.

132. According to the manner of pitching a roof in one or more directions, there is given to it a particular name, which may express the character of the whole roof, or merely name one of its characteristics. A *flat* roof is one where there is but a slight pitch, or slant, to its timbers, just sufficient to cause the water to run to its lower edge, which is called the **eaves.**

The amount of pitch usually given to a flat roof varies from $\frac{1}{4}$ inch to 3 inches to a foot, according to circumstances; when the inclination of the roof materially exceeds 3 inches to the foot, the roof comes under the class of *single-pitch*, or shed, roof, sometimes called a *lean-to*, as shown in Fig. 44.

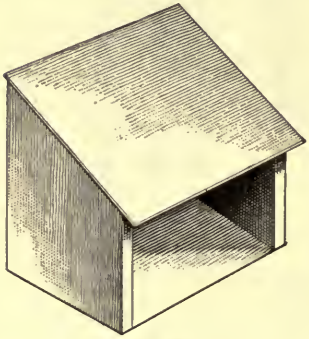


FIG. 44.

This kind of an enclosure is usually built against the side of another structure, already erected —hence its name *lean-to*—and its roof often has to receive and carry the drip from the main roof above, as well as its own collection of moisture. The single-pitch roof, however, is also frequently used over verandas, and attic dormer-windows, and in other minor positions on the main building.

133. When the pitch falls in both directions from the center of the building, we have what is known as a double-pitch, or **gable,** roof, as shown in Fig. 45, the plan of which

is the rectangle *f g h i*. This form of roof derives its name from the shape of its ends, the triangle *a b c* being called a *gable*, one of which exists at each end of the building. The upper edge of the roof *b e* is called the *ridge*, and the lower edges, on each side, as at *c d*, are called the *eaves*. In the plan *f i* and *g h* are the eaves, while *j k* shows the position of the ridge *b e*.

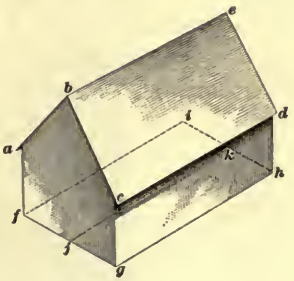


FIG. 45.

134. In Fig. 46 (*a*) is shown in perspective a square structure, with a gable on each of the four sides. The ridges of these gables intersect at *o*, while the eaves intersect in pairs at *a*, *c* and *e*; the line of intersection *o c* between the pitches *d c* and *b c*, is called a *valley*. At (*b*) is shown a plan of this roof, in which the lines *d' h'* and *f' b'* mark the positions of the ridges, the lines *o' a'*, *o' c'*, *o' e'*, and *o' g'* show the intersections of the slanting surfaces, called valleys, while the dotted outline *g' i' a'* is the form of the elevation of the gable over *g' h' a'*.

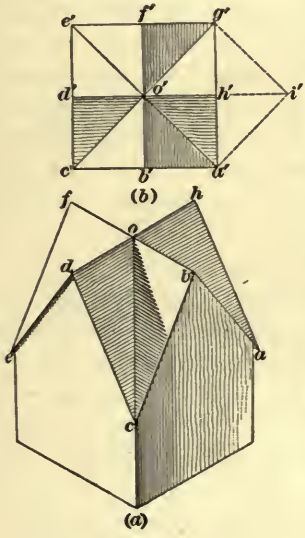
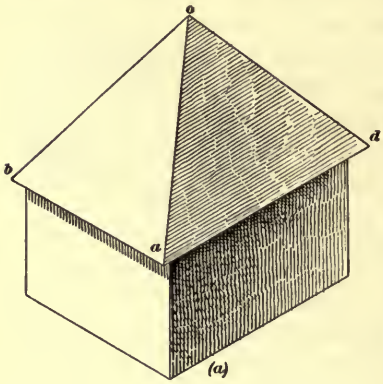


FIG. 46.

135. In Fig. 47 (*a*) is illustrated a rectangular building with a roof pitched back from all four sides, forming a pyramid. The edges *o a*, *o b*, and *o d*, in which these pitches meet, are called **hips**, and this type of roof is known as **hip roof**. As the building is not square, in this case, the pitch of the side *a o b* is different from the pitch of *a o d*, because the point *o'*, as seen in the plan (*b*), is the intersecting point of all four sides (called the *apex*) and is farther from *f'* and *h'* than from *e'* and *g'*; therefore, the

proportion of rise to run is different in adjacent sides, and the pitches are necessarily different.



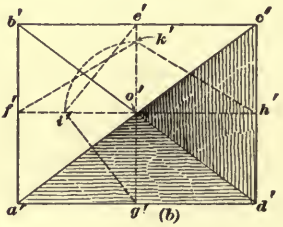


FIG. 47.

In the plan of this roof, shown at (*b*), the lines *a' c'* and *b' d'* show the position of the hips intersecting at *o'*. On the dotted line *o' e'* is laid off the distance *o' k'* equal to the height of the roof at the center *o'*, then the lines *k' f'* and *k' h'* show the pitch of the rafters, which are parallel to *o' f'* and *o' h'*. Likewise when the height of the center point *o'* is laid off, equal to *o' i'*, the lines *i' e'* and *i' g'* give the pitch of the rafters over, and parallel, to *o' e'* and *o' g'*.

136. In Fig. 48 we have the framing plan of a hip roof, where all four sides have the same pitch; being a parallelogram in form, its long

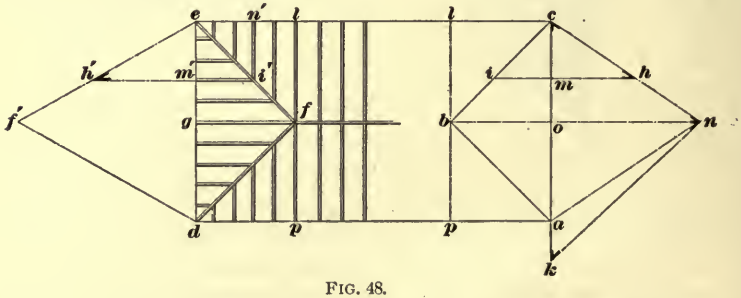


FIG. 48.

sides do not meet in an apex, as in Fig. 47, but form a ridge *f b*. If we lay off on the extended line of this ridge *o n* equal to the height of the ridge above the plate, and

connect *n c* and *n a*, we have, in the triangle *a n c*, the outline of a vertical section of the roof through any point on the ridge line *f b*, and *n c* or *n a* will be the pitch of the sides of the roof, as well as of the ends, as they are, in this case, both the same. The rafters between the points *f* and *b* will be parallel to *l f*, and their length will be equal to *n a*, as will also the length of the two rafters *f g* and *b o*.

The bevel of the ends of these rafters, where they rest against the ridge *f b*, called the **plumb-cut,** is the angle *c n o*, while the bevel on the other end, which foots upon the plate, called the **foot-cut,** will be the angle *o c n*. The four **hip rafters** *f e*, *f d*, *b c*, and *b a* will have a different length and bevel from those above named. This length and bevel are found as follows: Lay off *o k* perpendicular to *g o* and equal to *b c* or *b a*, on plan, make *o n* equal to the height of the ridge over the plate, and connect *k n*; then *k n* will be the length of the hip rafters, the angle *o n k* will be the bevel of the plumb-cut, and the angle *o k n* will be the bevel of the foot-cut.

137. The short timbers, whose lower end rests upon the plate, while the upper end rests against the hip rafter, as shown at *i m*, are called **jack-rafters,** and though they have the same plumb-cut and foot-cut as the ordinary rafters, they have an additional bevel on their upper ends called the **cheek-cut,** in order to have them fit nicely against the sides of the hip rafters, *b a*, *b c*, etc.

To find the length of a jack-rafter *i m*, draw *m h* from the foot of the rafter perpendicular to *c o*, and let it intersect *c n*, the roof slant, at *h*; then will *c h* be the length of the jack-rafter, and the angles *m h c* and *m c h* will be the bevels for the plumb-cut and foot-cut, respectively, which, as can be readily seen, are the same as for the ordinary rafters.

The *cheek-cut* of any jack-rafter may be found as follows: On the end of the roof, as at *d e*, draw the triangle *e f' d*,

making $e f'$ and $d f'$ each equal to $n k$, the true length of the hip rafters; prolong the line of any jack-rafter, as $i' m'$, till it intersects the side of this triangle, as at h', then the angle $m' h' e$ will be the cheek-cut for all the jack-rafters of that slope. If the slopes $f g$ and $f l$ are different, then to find the cheek-cut of the jack-rafters on the sides it will be necessary to erect another triangle on the side of the roof, making the base of the triangle equal to twice the distance $e l$, and the sides, as before, equal to the length of the hip-rafter $n k$. Any jack-rafter, as $i' n'$, may then be extended until it intersects with the side of the triangle just described, and the cheek-cut obtained as before.

138. Figs. 49 and 50 are plans of a gable-and-valley roof, and a hip-and-valley roof, which, though differing somewhat in appearance, contain no constructive principle not existing in Figs. 46 and 47. The four gables $t z s$, Fig. 49, are precisely similar to the four gables in Fig. 46, but are brought forward from the sides of the square $a\, a'\, a\, a'$, giving the building the form of a cross, as shown. The dotted line $z v$ is drawn equal to the height of the ridge $z z$ above the eaves, and the lines $v t$ and $v s$ are then drawn, giving the length of the rafters and their plumb-cut and foot-cut, as shown in Fig. 48. If on the valley line $x a$ we lay off $x o$ equal to the height of the ridge and draw $o a'$, then will $o a'$ be equal to the length of the *valley rafter* under the valleys $x a$, and $x a'$, and the angles $a' o x$ and $o a' x$ will be the plumb-cut and foot-cut respectively. The length and cuts on the jack-rafter $b c$ are found in the same manner as described in Art. **137,** though the cheek-cut in this case is on the lower end of the rafter instead of at the top. If the lower end b of the jack-

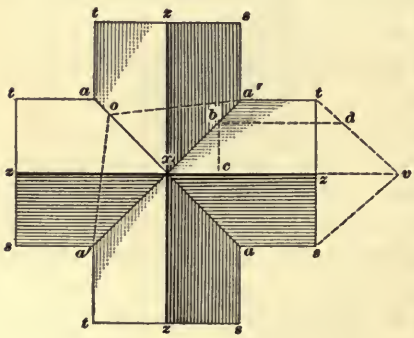


FIG. 49.

rafter $c\,b$ is projected up to d, the length $d\,v$ will then be the length of the jack-rafter, and $d\,v\,z$ will be the angle for its plumb-cut at the top, and $b\,d\,v$ will be the angle of its *plumb-cut at the bottom.* For, as neither of these jack-rafters rests upon the plate of the building, they will have no horizontal cut, and when in position the cuts on both upper and lower ends must be vertical, or plumb. The cheek-cut, as marked upon the *valley jack-rafter*, is found exactly in the same manner as for the hip jack-rafter, except that it is reversed; that is, if $e\,f'$ in Fig. 48 were a valley rafter, the angle $e\,h'\,m'$ of the jack-rafter $i'\,m'$ would be on the *bottom* of the rafter, and not the top, as with the hip-rafter.

139. The hip-and-valley roof in Fig. 50 is, in outline, precisely the same as the roof in Fig. 49, but in its plan of construction it has no gables. The four ends of the two parallelograms forming this plan have each two hips, as at $x\,r$—eight altogether—and there are four valleys, $z\,s$, $z\,m$, $z\,n$, and $z\,a$, with two ridges, $x\,x'$ and $b\,b'$. If we now draw $x\,t$ and $x'\,t'$, each at right angles to $x\,x'$ and equal to the height of roof, and connect $t\,t'$, the elevation of the ridge, with g and g', we have in $g\,t\,t'\,g'$ a vertical section of the roof on the line $g\,g'$. Now, if we draw $z\,e$ equal to $z\,o$ and connect $e\,m$ and $e\,a$, we have, at $m\,e\,a$, a vertical section of the roof valleys $z\,m$, $z\,a$. To obtain a vertical section of the roof through $m\,n$, we make $b'\,h$ equal to the height $x\,t$ and connect $h\,m$ and $h\,n$. The lengths and cuts of the hip-and-valley rafters can now be found according to the methods already given.

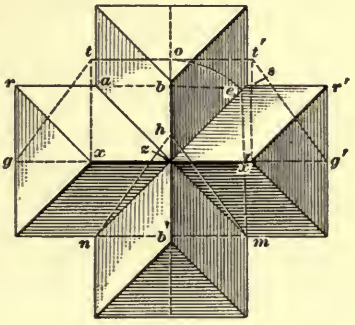


FIG. 50.

140. The **gambrel** roof is shown in Fig. 51; the term *gambrel* signifies a bend, or crook, and in this case

emphasizes the break in the continuity of the roof plane.

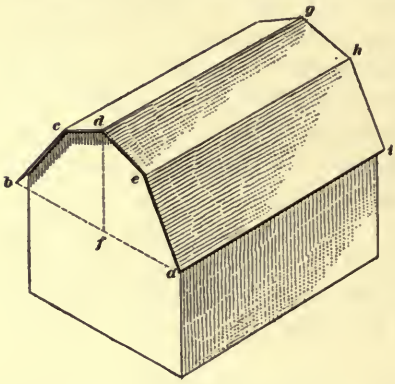


FIG. 51.

The ends of this roof are always of the gable form, as shown at *a b c d e*, but the slope from the ridge to the eaves is broken, the upper part *c d e* being somewhat flat, and the lower parts *c b* and *e a* decidedly steep.

This form had its origin in the endeavor to provide a roof that would secure more space in the garret, or attic, by increasing the height near the eaves, where a straight gable would give no head room. Its prototype is found in the *Mansard roof*, which was the invention of a Frenchman, whose name it bears.

The proportions of the example in Fig. 51 give the rise *f d* as equal to one-half the span *b a*, which is the common proportion of this form of roof; the pitch *d e* should never be more than 30° from the horizontal, and the inclination *e a* should not be less than 60°.

In framing a gambrel roof it is always necessary to have a plate or curb at *e h*, as well as at *a i*, the rafters between them being cut to foot on *a i*, and to rest their plumb-cut against *e h*. The rafters between the ridge *d g* and the plate *e h* are cut in the same manner for ridge and plate as in an ordinary gable roof, the plate *e h* being securely tied across the building to keep it from spreading under the thrust.

141. The **Mansard** roof, sometimes called a curb roof, is shown in Fig. 52, and, as will be seen, it resembles the gambrel roof in having a very flat top *a b c d* and very steep sides *a d f e* and *d c g f*. Its points of difference, however, are equally prominent; for, while the gambrel roof has its ends always enclosed with gables, the Mansard

roof is always the same on all sides, therein somewhat resembling the hip roof.

The sides of the Mansard roof are generally, though not always, curved, and are much more nearly perpendicular than the sides of the gambrel roof, as, in reality, these lower slopes of the Mansard are nothing more than continuations of the side walls of the building. In fact, the distinguishing characteristics between the gambrel and the Mansard roofs may be said to be that the former is an endeavor to make the inside of the roof appear like an upper story, while the latter is an effort to make the outside of the upper story look like part of the roof.

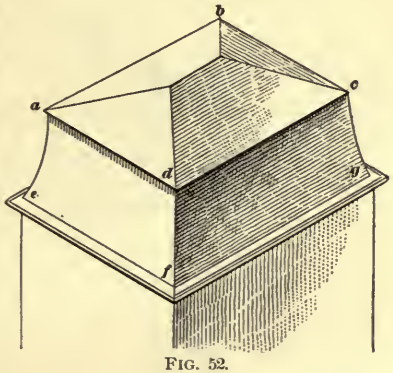


FIG. 52.

The relative pitch of the top and side slopes of a Mansard roof may be determined in several ways, one of which, known as Belidor's method, is shown in Fig. 53.

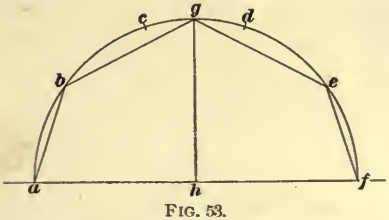


FIG. 53.

Upon the center *h* of a line *a f*, representing the span of the roof, a semicircle *a c d f* is drawn and its circumference divided into five equal parts at *a*, *b*, *c*, *d*, *e*, *f*. By connecting *a b* and *e f* the pitch of the sides of the roof is obtained, while on connecting *b* and *e* with the ridge or apex at *g*, the proper slope for the top or summit slope is secured.

Variations from this rule are common in practice, but the above proportions are such as will usually give most satisfactory structural results.

142. In Fig. 54 is shown a plan (*a*) and the section (*b*) through the lower slope of a Mansard roof, while at (*c*) is shown the elevation of the angle rib at *a e* or *d f* in Fig. 52.

In the plan (*a*) *u k″ x* is a corner, or angle, of the building at the lowest portion of the sloping sides of the roof, and is designated by *k* in the section (*b*). The line *s h y*, in the plan, is the upper edge of the sloping side, designated in the section (*b*) by *r*. If we now project up from the curved side in the section (*b*) any number of points, such as *c*, *d*, *r*, marking their intersections with the line *k″ g*, at *j*, *i*, *h*, and from these points, and at right angles to *k″ g*, lay off the lines *j l′*, *i m′*, *h n′*, equal to *c l*, *d m*, and *r n* in the section (*b*), we have, at *l′*, *m′*, *n′*, points in the curve of the angle rib which, if connected by a curved line, will give the profile sought.

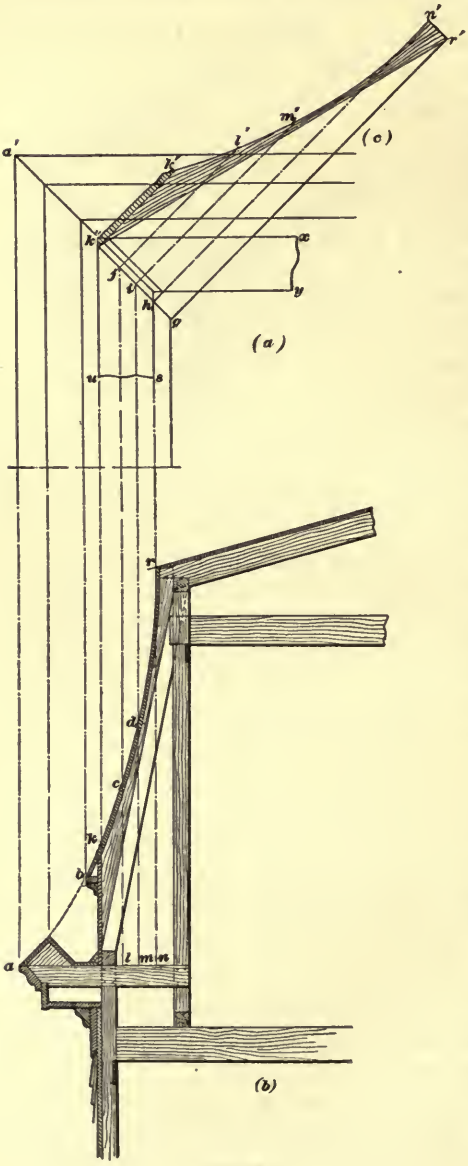


FIG. 54.

The distance *k″ k′* on the angle rib (*c*) is the height of the point *k*, in the section (*b*), above the bottom of the main slope at *a*.

143. In Fig. 55 is a framing plan (*a*) and sectional elevation (*b*) of a conical roof, the height of which is *c b* and the pitch *b a*. The rafters *a b* are notched over the plate in the same manner as though the roof were a plain gable, but the mitering of the upper ends is somewhat different, and can be best understood by reference to the plan (*a*).

The first pair of rafters *m*, *m* have a plumb-cut exactly the same as a gable rafter, and are butted squarely together at *r*, while the second pair *y* are similarly cut and butted and spiked at their upper ends against the first pair. The rafters *z* are then cut the same as *y*, but with the addition of a cheek-cut at an angle of 45° on *both* sides of the upper end; and the rafters *x* are made similar to *z*, except that the cheek-cuts are each $22\frac{1}{2}°$, instead of 45°.

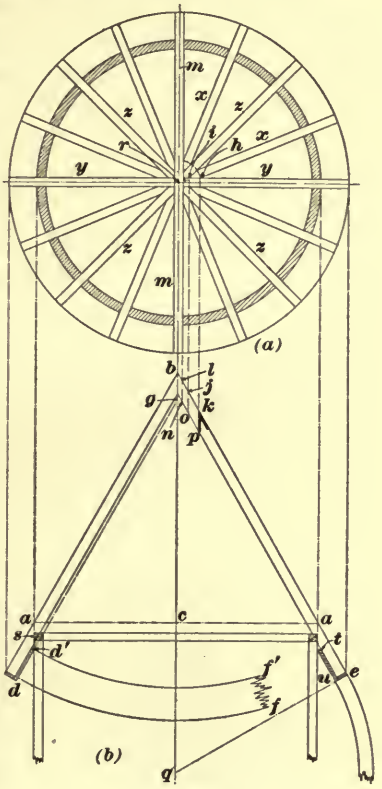


FIG. 55.

In the elevation (*b*) the rafters are shown overhanging the plate from *a* to *e* in order to form the eaves, and the length *c b* will be the length of the two rafters shown in the plan at *m*; from *b c* is then measured off, at right angles, the half thickness of the rafter *m*, and through the point thus located, a perpendicular line is drawn, cutting the rafter at *n l*; then will *e l* be the length of the rafters shown in the plan at *y*. The point *i*, where the edge of the rafter *z* intersects the edge of the rafter *y*, if projected down to the elevation (*b*), will cut the elevation of the rafter at *o j*, and *j e* will then be the length to the cheek-cut, of the rafters shown

in the plan at z. The length of the rafters x to the cheek-cut is then found by projecting the points of intersection, of adjacent sides of x and y, to the top of the rafter in elevation, cutting the rafter at $p\,k$; $k\,e$ will then be the length of the rafters to the cheek-cut, as shown in the plan at x. The angle $e\,k\,p$ will be the plumb-cut for all the rafters in the roof.

144. The wall plate, shown in the elevation at s, is cut out of two thicknesses of 2-inch plank, each piece being long enough to receive the feet of four rafters. When the plate is built in position, it is laid up in two thicknesses, no two joints of which are to be in line perpendicularly, and the joints on the under side to be well supported by studs.

The under side of the rafters, where they project beyond the plate, is sometimes lined, or sheathed, with a board $t\,u$ called the **plancher,** or soffit, and the ends of the rafters at $e\,u$ are then faced with a board called the **facia.** The proper curvature of the edges of the plancher $d\,f$ is found by drawing the line $d\,g$ parallel to the inside of the rafter, and at a distance from it equal to the thickness of the plancher; this line will intersect the axis $b\,c$ of the roof at g; then, with g as a center and radii $g\,d$ and $g\,d'$, describe the arcs $d\,f$ and $d'\,f'$, which will give the curvature required. The length of the plancher on the line $d\,f$ will, of course, be equal to the circumference of the roof at d.

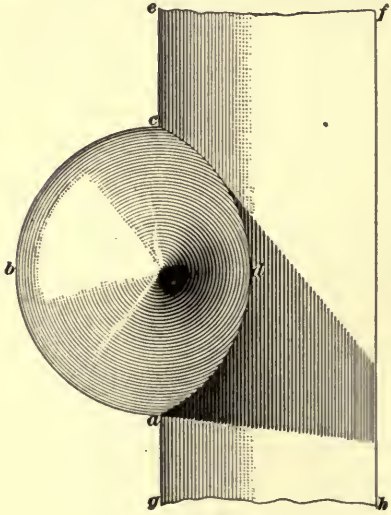


FIG. 56.

The roofing boards over the rafters are applied in the same manner as is described hereafter, in connection with the covering of domes, illustrated, subsequently, in Art. **205.**

145. Where a conical roof intersects the pitch of another roof, it is necessary

to resort to particular framing in each case. Fig. 56 shows the plan of a conical tower roof *a b c*, intersecting a flat single slope *e f h g*, the line of intersection being the curve *a d c*.

In Fig. 57 the plan *A* of the tower is divided into sixteen

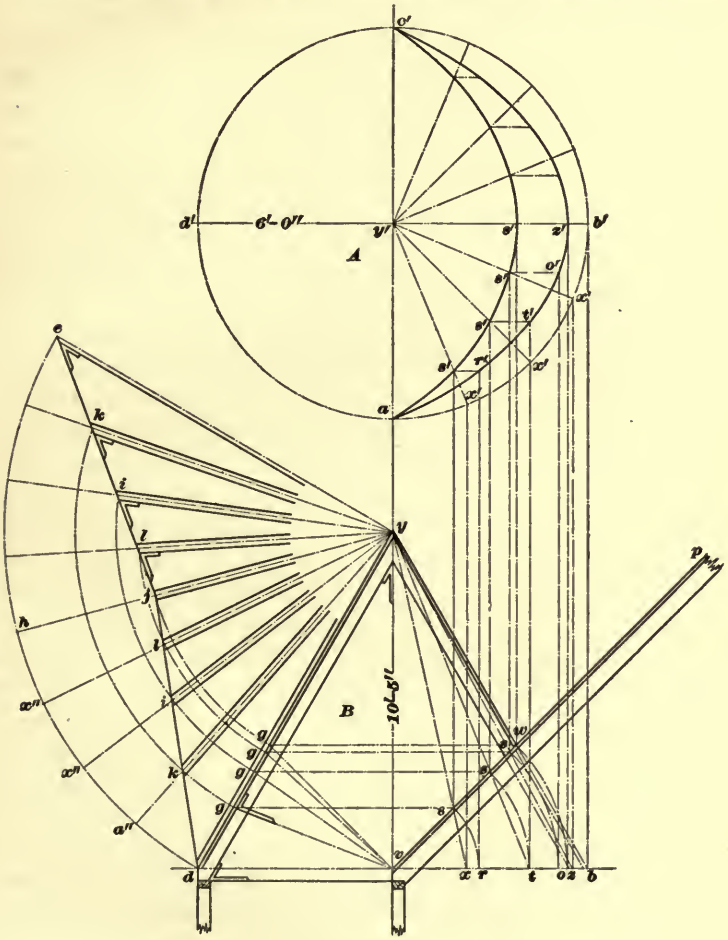


FIG. 57.

equal parts by the radial lines $y'\,a'$, $y'\,x'$, $y'\,b'$, etc., each one of which represents the center line of a rafter. The sectional elevation *B* shows the apex of the roof at *y* and the

rafters and their slopes at $y\,b$ and $y\,d$, while $d\,b$ is the line of the plate. The rafter $v\,p$ shows the slope of the main roof to which it belongs, and the point w shows the highest point in the line of intersection between the conical tower and the flat roof.

If we now draw the lines $y\,x$, $y\,t$, $y\,z$, etc., where the points x, t, and z are the projections of the points x' in the plan, these lines will indicate the position of the tower rafters in the elevation, and where these lines intersect the main roof slope at s, will be points in the curved line of intersection, between the two roofs.

Projecting the points s on each rafter to the plan of each rafter at A, we get the points s', which are all in the line of intersection between the two roofs, as shown at $a\,d\,c$, in Fig. 56, and through which the line of intersection $a'\,s'\,c'$ can be drawn, in Fig. 57. Horizontal lines drawn from the points of intersection s to the outside of the rafter, or slope line $y\,d$, will give the length $y\,g$ of each of the rafters $y\,s$.

The plumb-cuts at y and the foot-cuts at d have already been described in connection with Fig. 55, but the foot-cuts of the rafters, where they rest on the surface of the roof $v\,p$, are found as follows: With y as a center and a radius $y\,d$, draw the arc $d\,h\,e$, on which space off the feet of the rafters, as at a'', x'', x'', etc., and to these points draw radial lines from y. Make $y\,j$ equal to $y\,w$ the length of the shortest rafter, and draw $j\,e$ and $j\,d$; then the angle which $j\,e$ or $j\,d$ makes with the foot of each rafter will be the cheek-cut of that rafter on the roof, and a line $g\,v$ drawn from the foot of each rafter $y\,g$, will give the angle $y\,g\,v$, which is the bevel of the foot-cut of each rafter as it rests upon the roof $v\,p$.

The line of intersection between the two roofs, as shown in the elevation at $v\,w$, is seen in the plan A at $a'\,s'\,c'$, and being at an inclination, does not exhibit its exact curvature as it would appear if seen in a horizontal position. To find the points in the line of the true curve, proceed as follows: With v as a center with radii $v\,s$, describe the ares $s\,r$, $s\,t$, $s\,o$, etc., and where these ares intersect the line $d\,b$ erect the perpendiculars $r\,r'$, $t\,t'$, $o\,o'$, etc. From the points s', in the

plan *A*, draw the horizontal lines $s'r'$, $s't'$, $s'o'$, etc., and where these intersect the perpendiculars just described, will be the points in the curve required, through which points the true curve $a'r't'o'z'c'$ may be described.

The advantage of finding this curve is that from it a paper templet may be made with the points $a'r't'o'$, etc. located on it, and the curve may thereby be marked out on the boards of the roof vp, and the rafters of the conical roof footed upon the points $r't'o'$, etc. with great exactness.

Where the tower roof dyb is of large size, and is liable to throw considerable weight upon the main roof vp, short pieces of timber should be framed in between each of a pair of rafters where one of the tower rafters is to set its foot. On small towers the boarding of the roof is usually of sufficient strength in itself, and requires no timbers inserted beneath it.

146. A **hexagonal** roof and the system of framing it is shown in plan in Fig. 58, where the six hip rafters radiate from the center *o* to the corners of the hexagon *h f b g*, etc. The two pairs of rafters *c o j* and *g o h* should be set in place first, as in the conical tower, Fig. 55, and the other hip rafters are then fitted against them. To find the plumb-cut and foot-cut for these rafters, lay off *o a* equal to the height of the roof, and join *a* and *b*; then the angle *o b a* is the bevel of the foot-cut, and the angle *o a b*, the bevel of the plumb-cut, while the distance *a b* is the length of the hip rafter.

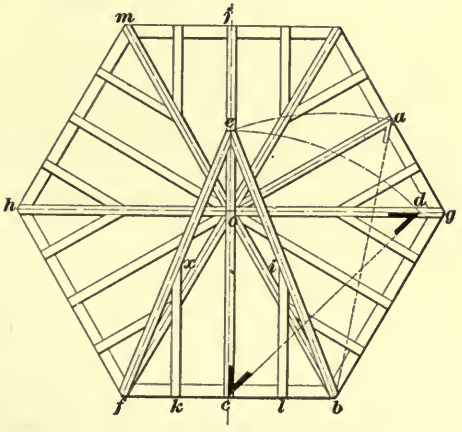


FIG. 58.

The middle rafters *o j*, *o a*, *o c*, etc. are found by laying off

the height of the roof at $o\,d$ and joining d and c; then the angle $o\,c\,d$ is the foot-cut, and the angle $o\,d\,c$ is the plumb-cut on the rafters $o\,j$, $o\,a$, $o\,c$, etc., and their length is equal to the distance $d\,c$.

If from b we now lay off $b\,e$ equal to $b\,a$ the length of the hip rafters, and draw the lines $e\,b$ and $e\,f$, on each of which, as a center line, the thickness of the rafter is laid off, we can draw in the jack-rafters $k\,x$ and $l\,i$; then the angle $f\,x\,k$ will be the bevel of the cheek-cut, and the angle $o\,d\,c$ will be the angle of their plumb-cut, which is similar to that of the rafter $o\,c$, to which the jack-rafters are parallel.

147. Sometimes a tower, or other small structure, is covered with a roof whose outline is composed of curved lines instead of the usual flat slope. This curved outline is usually compound in form; that is, one end is convex and the other is concave. When such a sloped roof is put upon a circular tower, it is called a **bell** roof, on account of its resemblance to the shape of a bell; but when applied to a square, or polygonal tower, we call it an **ogee** roof, from the fact of its outlines being of an *ogee*, or double curved, shape.

148. In Fig. 59 we have the plan (*a*) and sectional elevation (*b*) of the *ogee roof* of a square tower. The ribs, or rafters $a\,t$ and $t\,b$, shown in the plan (*a*), are either sawed or bent to the required shape, fitted squarely together at the top, and fastened in place. The ribs at $f'\,t$ and $g'\,t$ are next fitted, but are each shorter in length than the former pair by half the thickness of $a\,t$ or $t\,b$. The hip ribs $l\,t$, $q\,t$, $m\,t$, and $r\,t$ are now put in place, and finally the jack-rafters $o\,h$.

To determine the length and curve of the hip ribs, or rafters $l\,t$, $q\,t$, etc., draw $t\,x$ at right angles to $l\,t$ and equal in length to the height of the roof $c\,d$; divide the rib $f\,d$ into any number of parts, by making points as at v, and from these points erect perpendicular lines $v\,s$ parallel to $d\,c$; where these lines intersect $l\,t$ at s, draw the lines $s\,x$ at right angles to $l\,t$, making $s\,x$ in each case equal to the corresponding $r\,v$ in the elevation (*b*); through the points x draw the

curve *x x x*, which will be the profile of the angle rib required.

The length of the jack-rafters *o h* is found by dropping the perpendiculars *o k* and *i j* from each side of their cheek-cuts

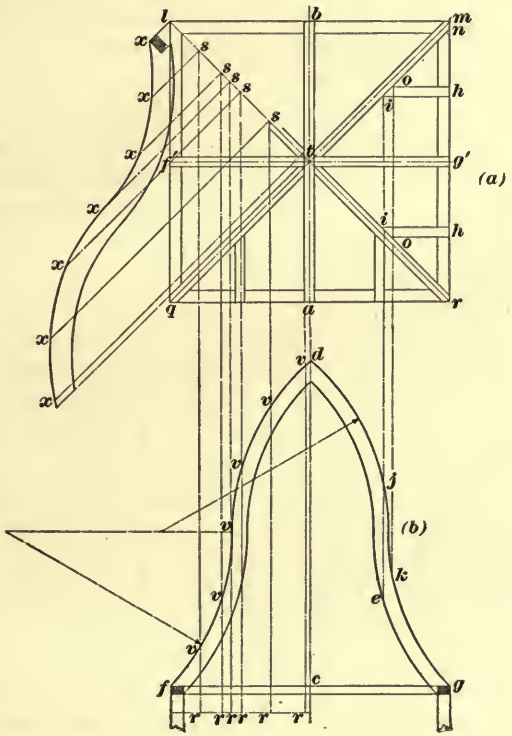


FIG. 59.

parallel to *c d*, and intersecting *d g* at *k* and *j*; then will *j g* be the extreme length and proper curve of the jack-rafters, while their plumb-cut will be on the line *j e*. The cheek-cut of these jack-rafters is found by drawing a line from *j* on the outside of the rafter, to *k* on the inside, which is shown in the plan (*a*) by the line *i o*. The hip rafters *l t*, *m t*, etc. must have their upper edges beveled on each side of the center line, as shown in the plan at *m n*. This is done in

order that the boarding of the roof may have an even bearing on the angle rib, and the edges of the boarding must meet accurately on the center line of the rib *m t*. The amount of bevel required on the angle rib is found by drawing a line with a scratch gauge parallel to the upper edge, and at a distance *m n* below this edge; the wood between this line and the center of the top of the rafter is then cut away.

149. When two gables of different heights and spans intersect, the framing of the valley rafters is somewhat different from the case where both gables are the same height. Fig. 60 is the plan of a portion of a gable roof

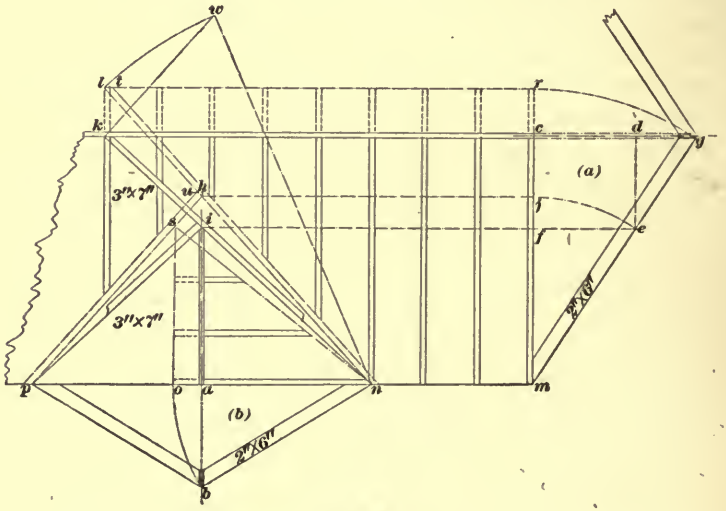


FIG. 60.

where a smaller gable at (*b*) intersects its slope. The inclination of the main gable (*a*) is laid off at *g m*, and the elevation of the end of the smaller gable (*b*) is drawn at *p b n*. The height *a b* of the smaller gable is laid off at *c d* and the line *d e* is drawn parallel to *c m*; *e i* is then drawn parallel to the ridge *k c*; *f e*, therefore, represents the height of the smaller gable in comparison to the large one, and *e* is the

point of the slope where the ridge gable (*b*) will intersect; therefore, by drawing the ridge line *a i* of the gable, we intersect the line drawn from *e* parallel to the small main ridge at *i*, and the lines *i p* and *i n* will, therefore, be the lines of the valley rafters of the small gable, as seen in plan. But, in framing our roof, we will carry one of these valley rafters *i n* past the point of intersection *i* to the main ridge at *k*, in order that it may have a firm support at its upper end. The rafter *n k*, therefore, will have its plumb-cheek and foot-cuts the same as though the intersecting gables were of the same height.

The rafter *i p*, however, though cut at the foot with the same bevel as is *n k*, has a different cut at *i*. With *m* as a center and a radius *m g*, we strike the arc *g r*, and with the radius *m e* we strike the arc *e j*; drawing *r l* and *j h*, *l r m* will be the plan of the roof on the flat surface, as though there were no pitch at all, the plan then shows the rafters at their true lengths and bevels. The rafter *n k* will, in this revolved plan, occupy the position *n l*, and *l t* will be its cheek-cut, while the rafter *p i* will now appear at *p h*, and *u h* will be the bevel of its cheek-cut. The plumb-cut of the rafter *n k* will be on the angle formed at *w* by making *k w* equal to *c g* and perpendicular to *n k*, and drawing *w n*; the bevel of the foot-cut will be the angle *w n k*.

The lengths and bevels of the jack-rafters in the main roof are shown in their true proportions in the revolved plan *l r m*, and can be scaled from that, while the necessary measurements for the jack-rafters in the small roof (*b*) can be obtained by revolving the pitch *n b* on *n* as a center until it lies on the level plane *n o*. The triangle *o s n* will then be the actual shape and proportion of one slope of the small gable roof, and the length and bevels of the jack-rafters can be scaled therefrom.

If the line *p n* from which the small gable springs should be, instead of at the eaves, as in this case, at some point on the slope of the roof above the eave line *p m*, the valley rafters *h n* and *h p* would be carried down to the plate, as at *u'* and *v'* in Fig. 72, in order to secure them a good footing, and

a piece of timber t' would be framed, from which the short rafters q' would extend to the eaves. Sometimes, when the main gable is very large and the smaller one is much less in size, the valley rafters are not carried down to the plate, as above described, but are simply framed into the nearest common rafter on each side and a rod is put through along the side of the piece which is shown framed at t; this rod, when its nuts are screwed up tight on each end, prevents the common rafters from spreading under the thrust of the valley rafters framed against them.

150. It is sometimes desirable, in framing a roof, to make the rafters of very heavy material and space them much farther apart than in ordinary cases, as is always done when trusses are used in the roof.

In order to properly fasten the roofing material to these widely spaced rafters, it is necessary to introduce a series of small roof beams at right angles to, and with their ends resting on, the rafters. These roof beams are called **purlins**, and though they possess neither plumb-cut nor foot-cut, they have a peculiar miter-cut, where they meet on hips or in valleys, illustrated in Fig. 61, in which $a\,b\,c\,d$ is the plan of a roof with two slopes meeting on the hip $d\,b$. From d we lay off $d\,e$ perpendicular to $d\,b$ and $d\,f$ parallel to $a\,b$, and each equal to the height of the roof; then $e\,b$ will be the slope of the roof over the hip $d\,b$, and $f\,a$ will be the slope of the roof over the common rafter $d\,a$; $g\,h\,j$ is a purlin on the slope of the common rafters, and the dotted lines $j\,l$, $h\,m$, and $g\,n$ show the position of the purlin in plan, and $l\,m\,n$ the direction of its miter on the hip rafter $d\,b$. The line $l\,s\,o$ is now drawn square across the plan of the purlin.

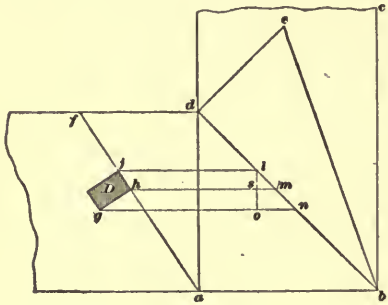


FIG. 61.

Fig. 62 is a perspective sketch of the purlin, where the line $v\,z\,x$ is drawn square across each side of the timber, and $z\,r$ and $x\,y$ are laid off equal, respectively, to $s\,m$ and $o\,n$, Fig. 61. The line $v\,r\,y$ is, then, the bevel on which to cut the miter of the purlin.

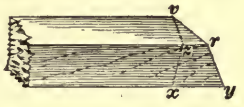


FIG. 62.

151. When rooms are divided in the attic, or under the roof of a building, and the partitions run neither parallel to the rafters nor to the ridge, the studs have to be cut at their upper ends to fit an inclined plane which passes over their diagonally opposite corners.

Fig. 63 shows at $a\,b\,c\,f$ the plan of a stud, the sides of which are parallel neither to the rafter line $m\,l$, nor to the eave line $l\,i$. The line $k\,l$ shows the pitch of the roof over $m\,l$, to the plane of the under side of which the stud is to be fitted. The lines $f\,j$, $c\,h$, and $b\,d$, therefore, are the corners $f\,c\,b$ of the stud in elevation, and at $j\,h\,d$ are the points where these corners intersect this roof pitch. By drawing $d\,n$ at right angles to $d\,b$, we find that the corner of the stud c is longer than the corner b by the length of the line $e\,h$, and the corner f is longer than the corner b by the length of the line $n\,j$. Therefore, if we draw a line around a stud, square with each edge, as $t\,o\,p$, in Fig. 64, and lay off $t\,s$ and $o\,r$ equal to $n\,j$ and $e\,h$, in Fig. 63, we have, on connecting the points $s\,r\,p$, the bevel line of the end of the stud, as required.

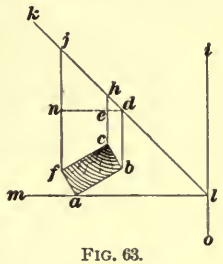


FIG. 63.

FIG. 64.

THE USE OF THE STEEL SQUARE.

152. One of the most useful tools in the carpenter's kit is the **steel square,** as with it may be solved a number of problems which would otherwise require extensive drawings, or tedious calculations. Fig. 65 shows the regular form of this instrument; the length of the blade $a\,c$ is always 24 inches, and that of the tongue $a\,b$ varies, in different squares,

from 12 inches to 18 inches. The corner *a* where the blade and tongue meet, is called the heel.

153. In marking the plumb-cut or foot-cut on a rafter, where the pitch of the roof is known in the proportion of

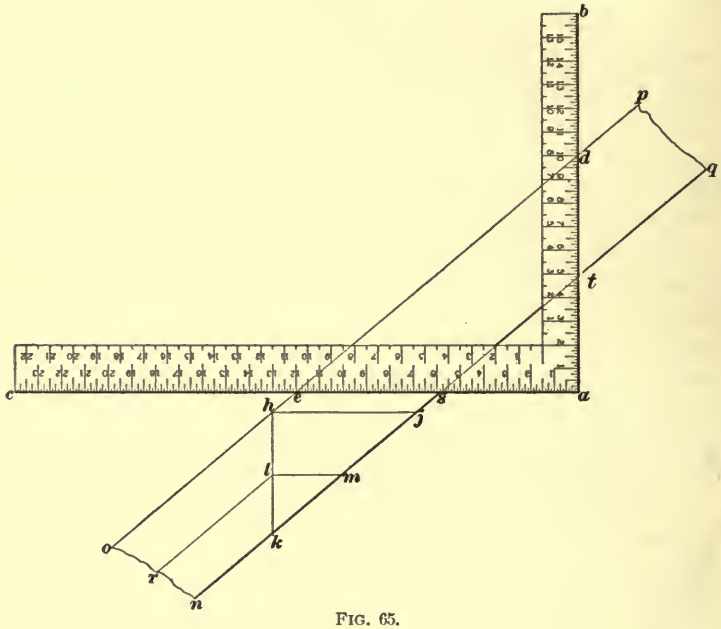


FIG. 65.

rise to run, it is only necessary to so set the square upon the rafter in such a position that the *rise* in inches, as shown on the tongue, and the run in inches, as read on the blade, are both in line on the same edge of the rafter; the tongue will then mark the angle of the plumb-cut, and the blade will mark the bevel of the foot-cut.

In Fig. 65 let *n o p q* be a rafter, the cuts of which are to be made for a roof in proportion of 10-inch rise to 12-inch run. The square is set so that the rise 10 inches is set off on the tongue at *a d*, and the run 12 inches is set off on the blade at *a e*; then the tongue will mark the plumb-cut *d t* at the ridge, and the blade at *e s* will mark the bevel of the foot-cut at the plate. If the rafter is to project beyond the

plate, mark the foot-cut *h j* and draw *h k* at right angles to it. In the center of *h k* draw *l m* parallel to *h j*; then *k l m* is cut out to notch over the plate, and the projection of the rafter beyond the plate is measured from *h* towards *o*. The length of the rafter may be determined by setting off the distance *e d* along the top of the rafter, once for each foot of half span in the roof, and the cuts at ridge and plate must be made from the ends of the rafter so determined. If the span is 24 ft. and the pitch is the same on each side of the ridge, the distance *e d* is set off twelve times from the plumb-cut *d t* to the top of the foot-cut *h*, beyond which the projection over the eaves is to be added, as explained above.

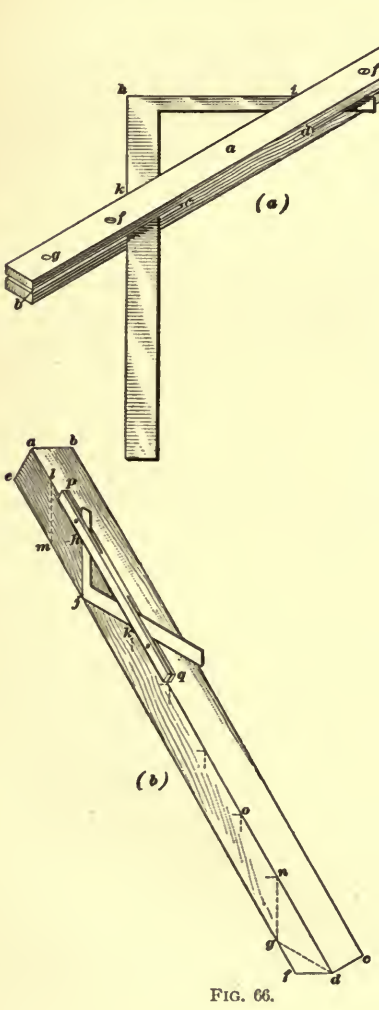


FIG. 66.

154. A very valuable appendage to the square is the simple device called a **fence**, shown at *a* in Fig. 66 (*a*). It consists of a piece of hard wood, preferably cherry or black walnut, 2 inches

wide, $1\frac{1}{2}$ inches thick, and 2 feet 10 inches long, with saw kerfs *b c* and *d e* cut in from each end to within 5 inches of the middle, thus leaving 10 inches of solid wood at *c d*. Two holes *f* and *g* are bored through each end, and two $1\frac{1}{4}$-inch No. 10 screws are then inserted, as shown at *f*, to bind the fence on the square.

The purpose of the fence is to do away with the use of the bevel in laying roof joists, angle beams, stair strings, etc. In the above case the fence can be set for the rise of the rafter at *h i* and the run laid off at *h k*; then, if the fence and square are applied to the scantling, as shown in Fig. 66 (*b*), the tongue will show the plumb-cut *l m* and the blade will give the bevel for the foot-cut *g d*.

In Fig. 66 (*b*), let *e a b c d f e* be a rafter and *h j k* a steel square with the fence *p q* applied for the proper rise and run of the roof. The fence and square are then placed at the lower end of the joist, and the line *g d* is marked for the foot-cut. At the same time the point *n* is marked on the scantling at the point *h* of the square. The fence is now slid along until the point *k* on the square coincides with the mark at *n* on the rafter, and the point *h* on the square is then marked at *o* on the rafter. This operation is repeated once for every foot of run in the roof, as shown by the dotted lines; then the last position of the tongue at *l m* will be the plumb-cut of the rafter, and the distance *l d* will be its top length.

CONSTRUCTION OF ROOFS.

155. In building the roof on a house, the rafters are nearly always carried beyond the front of the plate from 10 to 24 inches, in order that the drip from the eaves may fall clear of the wall of the house. Fig. 67 shows the method of cutting the rafters where they so project, and also a method of finishing and enclosing the rafters, and of forming a standing gutter.

A rafter *a b e f d c* is notched over the plate *g* at *c d* and projects beyond the plate at *d f*. The portion of the rafter below *d f* is cut away to lighten the appearance of the eaves, and the line on which to cut the rafter for it is shown at *m l r*, Fig. 65. At *h* is a tie-beam, which is spiked to the

ends of the rafter on each side of the building, and, in this case, forms, also, the ceiling beam of the upper story and rests on the plate *g*. From the top of the tie the rafter is closely boarded with 1-inch boards *k*, the lower one of which is allowed to project about half its width beyond the end of the rafter at *e i*. The end of the rafter is cut on the line *e f*,

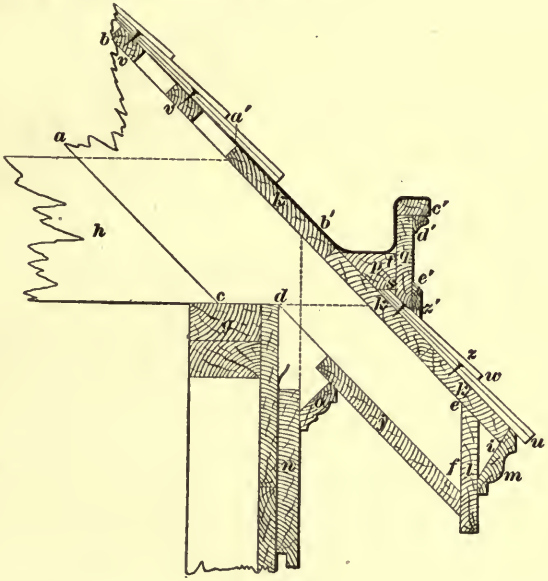


FIG. 67.

which is parallel to the plumb-cut at the ridge, and the soffit, or plancher, *j* on the bottom of the rafters has its outer edge beveled to the same angle, as is, also, the top of the facia *l*, which finishes the ends of the rafters. A crown molding *m* is then secured in place by nailing it to both the projecting roof-board *k* and the front of the facia *l*. This gives a finish to the projecting eaves, and the under side is completed by the insertion of the molding *o* between the soffit *j* and the frieze, or top casing, *n*. This finish is usually called a box cornice, in that it is formed by a boxing, or casing, of wood. Over the roofing boards, and outside the line of the front of the building, a bedplate *p* is nailed securely to each rafter, to form the gutter, as will be explained further on.

156. Roofs are variously covered with wood shingles, steel shingles, slate, tin, lead, zinc, corrugated iron, copper, or tiles. A flat roof should always be covered with tin, copper, or other material which is practically one piece, as water will run back between the joints of shingles, slates, or tiles, and thereby get into the interior of the building. A pitched roof may be covered with any of the above materials, but generally shingles, slate, or tiles are used.

157. **Shingles** are laid on the roof of the house, either upon sheathing boards, as shown at *k*, Fig. 67, or upon shingle laths, as shown at *v*. The latter method is preferable, as it gives better ventilation to the under side of the shingles and prevents the accumulation of moisture there. When boards are used as a roof covering upon which shingles are to be laid, they should not be laid close, as at *k*, except over the eaves. Shingle laths, shown at *v*, are usually $1\frac{1}{4}$ in. $\times 2$ in., or $1\frac{1}{4}$ in. $\times 3$ in., and are laid at right angles to the rafters, and from 4 inches to 8 inches on centers, according to the exposure of the shingles to the weather. The amount of this exposure also determines the length of shingles which can be used with the greatest economy of material consistent with first-class work.

Shingles vary in length, and can be obtained in regular sizes of 16 inches, 18 inches, 24 inches, and 27 inches in length, and from 4 inches to 7 inches in width. The size to be used in each case should be about 3 inches longer than three times its exposure to the weather.

The first course of shingles is laid at the eaves, and is laid double with broken joints, as at *u*, Fig. 67, in order that water finding its way through the joints of the upper layer, may not readily percolate through the lower layer and rot the roofing boards, facia, etc.

When the first course is laid, each shingle is nailed with two nails about 2 inches above the upper line of its exposure; the amount of exposure is then measured back from the lower, or butt, edge of the shingles, and a line is struck by means of a chalked cord, to which line the butts of the next course are laid, as at *w*. This protects the nails driven

in the previous shingles by the 2-inch lap shown at *z w*, and the nails of the second course pass, also, through the upper ends of the first course, as at *z'*.

158. After the shingling is completed up to the gutter plate *p*—which, in this case, requires but two courses—the gutter face board *q* is set in place with its lower edge beveled to fit the top of the shingles; a plinth *e'*, a cap member *c'*, and bed mold *d'*, may now be nailed in place.

In lining the gutter with copper or tin, it is well to nail a strip of hoop iron along the edge of the cap *c'*, allowing the lower edge to project below the cap. To this edge the metallic lining may be clasped, from which point it extends across the bed of the gutter to *b'* and up as far as *a'*.

In starting the course of shingles above the gutter, care must be taken that the butts are placed somewhat higher than the overflow of the gutter, so that they will be clear of the water when the gutter is choked; it is well to have the metallic lining extend for 5 or 6 inches under the shingles. When the first course of shingles above the gutter is laid, the course is doubled for the same reason that it is at the eaves, and the remainder of the roof from here up to the ridge is shingled, one course at a time, as explained above.

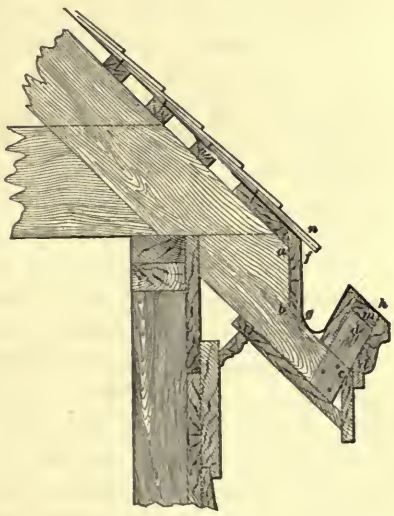


FIG. 68.

159. Another form of gutter is shown in Fig. 68, where the end of the rafter is cut out at *a b c*, and a short piece of timber *d* is spiked on the side of the end, as shown, to form the front edge of the gutter depression, while the back of the gutter is formed with a piece of $1\frac{1}{8}$-inch plank spiked on the end of the rafters at *a b*.

The lining of the gutter or flashing *f g h* is then bent in place and turned over the roof-board *m* and around the fillet of the molding *l*, where it is held in place by being clasped to the edge of a strip of hoop iron, previously attached to the fillet. The back of the lining is turned under the shingles at *f* and the first course of shingles *n* is laid so that the butts project 1 inch to 1½ inches over the edge of the gutter.

This form of gutter is generally invisible from the ground and permits an uninterrupted slope to the roof from the ridge to the eaves, so that accumulated snow may slide off without hindrance, and free the roof of its weight and dampness. It is objectionable, however, in some cases where the eaves project considerably, as will be shown further on, and if it is built up closer to the plate, or above the plate, it materially weakens the rafter. The necessary slope, or fall, of the gutter, in order to cause the water to flow towards the leader end, is accomplished, in this case, by cutting each succeeding rafter slightly deeper than the preceding one.

160. The lining of a gutter should be of the best quality of material, with all the joints properly folded, if of tin, and well soldered. It should be painted on both sides and well fitted to the gutter. The gutter plate *p*, Fig. 67, is made of a varying width so that the gutter has a gradual pitch towards the **leader,** or outflow pipe, which is located at the lower end. This leader is usually made of tin, corrugated galvanized-iron, or copper pipe from 2 inches to 6 inches in diameter, according to the size of the roof it must carry the water from; and where the roof area is very great, more than one leader may be necessary to carry off the accumulation of water during a heavy rain. A liberal allowance is to provide 1 square inch of leader section for each 75 square feet of roof area; but never to use a leader less than 2 inches in diameter. Even that size is liable to become choked and clogged with dirt or leaves, if in a wooded section of country, and should be used only for veranda, porch, bay window, and other small roofs.

The leader is inserted through the bottom of the gutter

and its metallic lining, and must be well soldered to the latter, while its **throat,** or inlet, should be countersunk, and protected with an open iron grating, or wire screen, to prevent foreign substances from entering with the water.

161. Flashing is a term given to all sheet-metal work used in connection with roof covering to insure a water-tight condition at joints and angles. Flashings are required on hips, valleys, ridges, and eaves, around scuttles, sky-lights, gables, flanks of dormer-windows, etc.

162. On hip roofs, where angle rolls are not used, pieces of flashing are laid on the *hip* over each course of shingles or slate in the same manner that a shingle or slate itself would be laid, if it could be bent to fit around the corner as shown at *a*, Fig. 69. For, while the joints between the various pieces of roof covering may be broken, or alternated, as at *b*, in the main flat slopes, the hips must have a continuous row of joints from the eaves to the ridge, as at *c*, and the insertion of flashings under the shingles, at these points, prevents the water that would work its way beneath the covering from getting into the interior, and carries it to the flat slopes, where it may harmlessly run off.

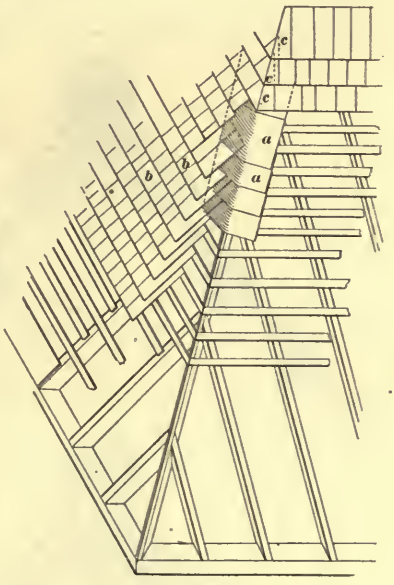


FIG. 69.

163. In valleys the means adopted are different, as the conditions are in some respects reversed. On the hip of the roof there is no accumulation of water at any time, and what little may fall there is immediately drained off by the

pitch; but in the valley we have a depression between two slopes, and all the water falling on each of them is immediately carried to the valley.

The valley, therefore, acts in the capacity of a gutter, and is flashed accordingly. The tin is joined, generally at the ends, to form a continuous gutter in the depression, and its edges are turned up under the shingles about 6 inches. The shingling is not carried down to the intersection of the slopes, but is stopped about 5 inches from the valley rafter, and the gutter, thereby, is left open. The flashing of all such situations will be treated in detail in *Sheet-Metal Work.*

164. Along the ridge the roof is rendered water-tight by a number of different methods, two of which are illustrated in Fig. 70, (*a*) and (*b*). At (*a*) is a method used on a shingle roof and requires no flashing, while at (*b*) a metal flashing is used on a slate, or flat tile, roof. At (*a*) the ridge plate *a* is carried above the line of the shingle lath *b* and the top of the shingles *d*, and its top is beveled off to conform with the general pitch of the roof. After the shingling is complete, the top of the ridge is finished off to form a continuation of the

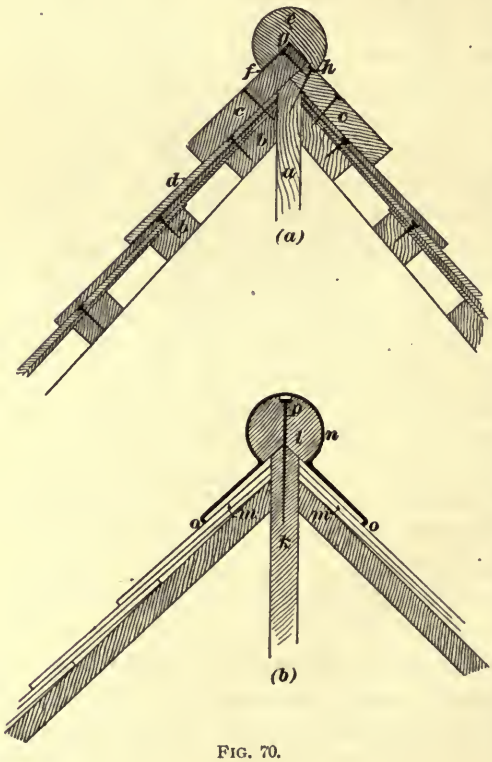


FIG. 70.

top surface of the last course of shingles, and the **ridge boards** *c* are nailed to it and to each other in the position shown. Before the ridge boards are nailed in place, there should be a layer of two-ply roofing felt folded over the ridge, on top of which the ridge boards may be firmly nailed; this will tend towards making a thorough water-tight job. These ridge boards are usually from 1 inch to $1\frac{1}{8}$ inches in thickness, and from $5\frac{1}{2}$ to 9 inches in width, according to the amount the shingles are exposed to the weather. The **ridge roll** *e* is formed from a single piece of wood, is from $2\frac{1}{2}$ to 3 inches in diameter, and is *rebated*, or *rabbeted*, at *f g h* to fit the angle at the top of the ridge boards; this **V**-shaped groove, or rabbet, should be deep enough to permit the edge of the roll *h* to lap well over the joint between the two ridge boards *c*.

At (*b*) the slating of the roof *m* is carried up to the beveled end of the ridge plate *k*, butting against it as the shingles do in (*a*), and the wooden ridge roll *l* is rabbeted over the joints formed at the ridge and the ridge plate. This roll is held in place by long spikes *p* driven through its top into the upper edge of the ridge plate, and over it is sprung the galvanized-iron covering *n*, which has been previously shaped to fit the roll and catch the under edge of the last course of slates, as at *o*.

Ridges, like hips, are very slightly subject to leakage, and, as little water falls on them, and practically none remains after it has fallen, we do not require the same precautions with flashings at these points as we require elsewhere.

165. Around skylights and dormer-windows, where the sill rests on the slope of the roof, flashing is applied so that it extends under the roof covering which is adjacent to the sill, and turns up and over the sill itself in such a manner as will prevent any possibility of water working its way between the sill and the slate or shingles. The sides of a dormer, where they intersect with the roof pitch, are flashed in the same manner as are the valleys, except that the

shingling or other covering may be carried up close to the finished sides.

166. Great care must be observed along the eaves of a roof, especially where that roof is over a well heated room, as the interior heat will, during the winter, cause the snow on the roof to melt and run to the eaves, where, relieved from the effects of the high temperature, it freezes and builds up a dam of ice, and the accumulated water backs under the shingles and gets into the house. Under these conditions it is sometimes desirable to build the gutter above the line of the plate, in order that the same heat that melts the snow may sufficiently warm the gutter to prevent it from freezing up when its services are most needed.

Unless the pitch of a roof is at least 45 degrees above the horizontal, there is much danger of leakage during windy weather, as a high wind will drive the water under the shingles and through the first crevice that presents itself. Hence, the importance of exercising the greatest care with all the flashings, and of securing broken joints in each course of shingles.

Shingles with loose knots or open knot holes within half their length of the butt, or shingles that are split, or shaky and liable to split, should be rejected, and rejected shingles should be broken or cut through with the hatchet, lest some other workman, with less precaution, be inclined to use them. The slight apparent waste thus caused is nothing compared with the expense and inconvenience of a leaky roof.

DORMER-WINDOWS.

167. **Dormer-windows,** a term applied to windows projecting from the roof of a building, are framed out when the roof is constructed. The size and the shape of the openings left for them between the rafters, depend upon the size and the character of their roofs.

Where a dormer-window is covered with a small gable, the main roof is framed for it in the manner described in Art. **149,** and where the covering is a flat pitch, somewhat

like the lean-to roof in Fig. 44, the opening in the rafters is left rectangular, with a header and a pair of trimmers, as was described in Art. **110,** except that the header and tail-beams are not usually mortised and tenoned into the timbers to which they are joined. The sides of dormers are studded and sheathed in the same manner as the outside walls of the house.

168. Sometimes these roof openings are very small, and introduced as much for ornament as for light or ventilation; this is particularly the case in the form known as the **eye-brow window,** shown in Fig. 71, in which (*a*) is its front elevation and (*b*) a sectional side elevation through the center of its roof. This elevation shows the curvature of each of the ribs *b*, *c*, *d*, etc. of the front elevation by the dotted lines *b'*, *d'*, *e'*, etc.

The example shown in Fig. 71 is 9 feet in length from *g* to *h*; the line *g h* is the top line of the main rafters, as shown at *g'*, while the line *s r* is the top line of the roof sheathing, shown at *s'*. The height *j p* is 2 feet and the curve of the front elevation of the roof *s p r* is formed with three arcs of circles, whose centers *t t* and *k* are located as follows: Prolong the center line *p j*, and with some point *k* as a center, describe the arc *u p v* with such a radius that the points *u* and *v*, where this arc intersects the lines *p r* and *p s*, will fall below *p* less than half the distance *p j*. Then from *k* the center of the above arc, draw through the points *u* and *v* the lines *k t*, and the points *t t* where these lines intersect *r t* and *s t*, drawn perpendicular to *s r*, will be the centers for the arcs *u r* and *v s*, which complete the compound curve of the top of the window. All the curved parts of the elevation are described from these centers, the arcs above the lines *k t* being described from *k* as a center, and those falling below the lines *k t* being turned on *t*, *t* as centers. The ribs, or rafters *a*, *b*, *c*, *d*, and *e*, are now spaced off to stand about 9 inches on centers, and, as will be observed, the top and bottom edges will be beveled to conform more closely to the curved outline of the roof, except the middle rib *a*, which is, practically, rectangular in section.

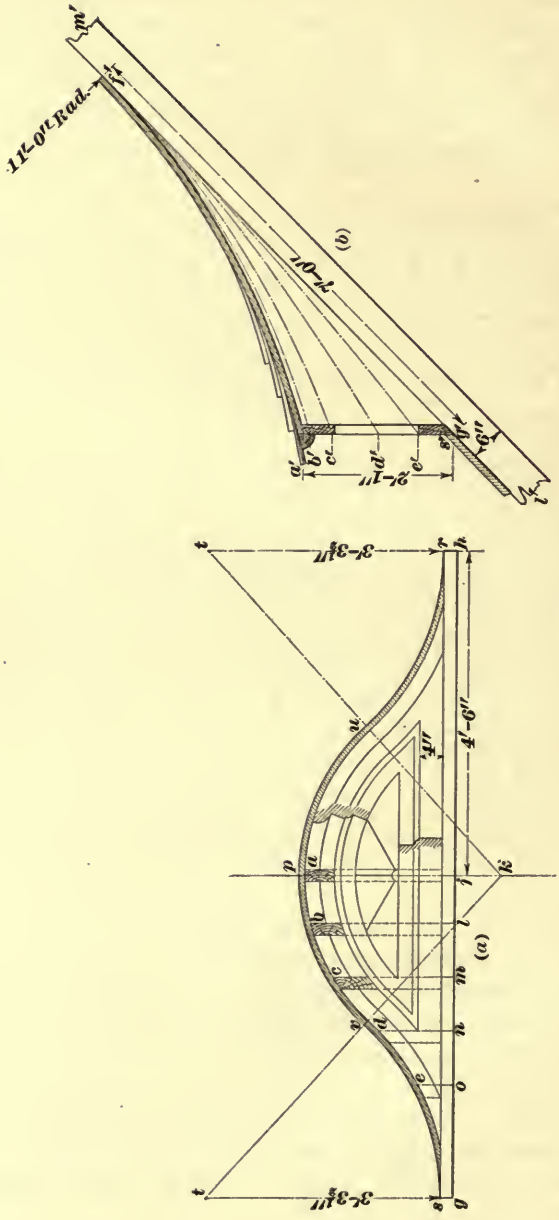


FIG. 71.

In the section through the center of the window shown at (*b*), a', b', c', d', and e' are the ends of the ribs, shown at at a, b, c, d, and e in the front elevation (*a*), and the lines $f'\,a'$, $f'\,b'$, etc. are the tops of these ribs and the profiles of their curvatures. The rafter $l'\,m'$ shows the pitch of the main roof, and the roof of the eyebrow window curves upwards towards it until it becomes tangent at f'. All the ribs $a'\,f'$, $b'\,f'$, $c'\,f'$, etc. become tangent at f', and the bevel of their top and bottom sides, shown in the front elevation (*a*), gradually diminishes as they recede, until at f they are all rectangular in section. The curvature of the ribs, as shown by the dotted lines $f'\,c'$, $f'\,d'$, etc., is determined by striking the curve of the uppermost rib with the arc of a circle, whose radius must be perpendicular to the rafter $l'\,m'$ at f', and the distances $g'\,e'$, $g'\,d'$, $g'\,c'$, etc. are laid off to correspond with $o\,e$, $n\,d$, $m\,c$, etc. in the front elevation. From each of the points e', d', c', etc. is then drawn the top line of the rib to f', varying the curvature in each successive rib to such a degree as will keep them the same relative distances below one another as at their starting points a', b', c', etc. The ribs are sawed out of 2-inch plank on lines developed as above described, and the shingle lath are bent over the curve and continued on the main roof without interruption, as the curved outline of the window removes all necessity of valleys, and, consequently, of flashing.

When the roof is shingled, the lines of the shingle butts are carried along over the eyebrow window, so that, in reality, it forms simply a protuberance of the main roof.

169. Windows of the same general character as the eyebrow window, are sometimes constructed with a flat, square roof, curving upwards slightly as it recedes towards the main roof, so that the side elevation and section are similar in shape to (*b*); but the ribs forming the roof construction are all alike and rest on a straight plate in front, while the sides are shingled, or sheathed, in the same manner as a dormer-window.

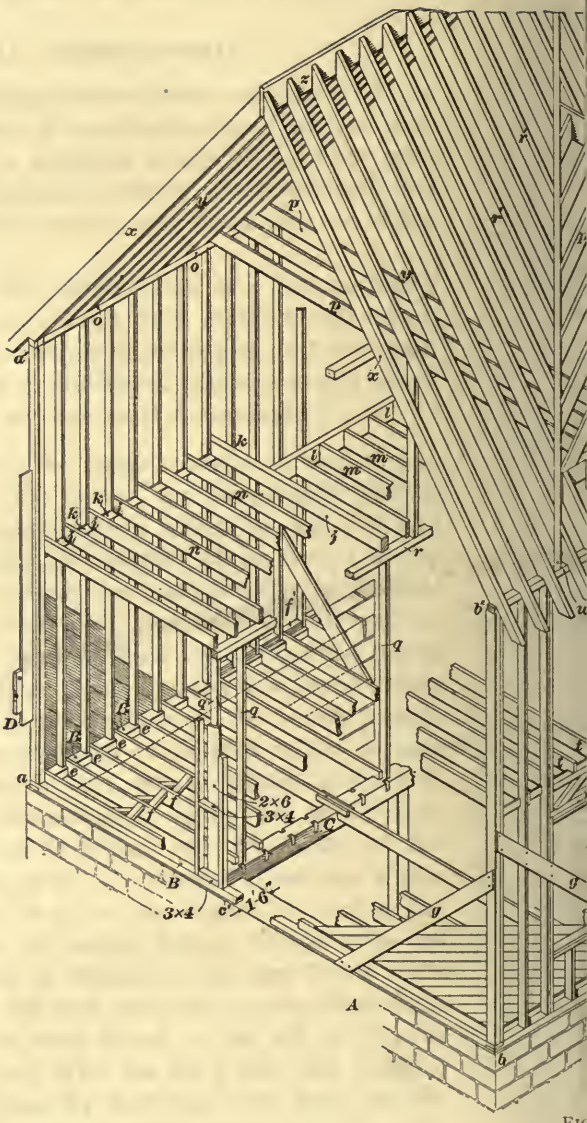
BALLOON-FRAME CONSTRUCTION.

GENERAL DESCRIPTION.

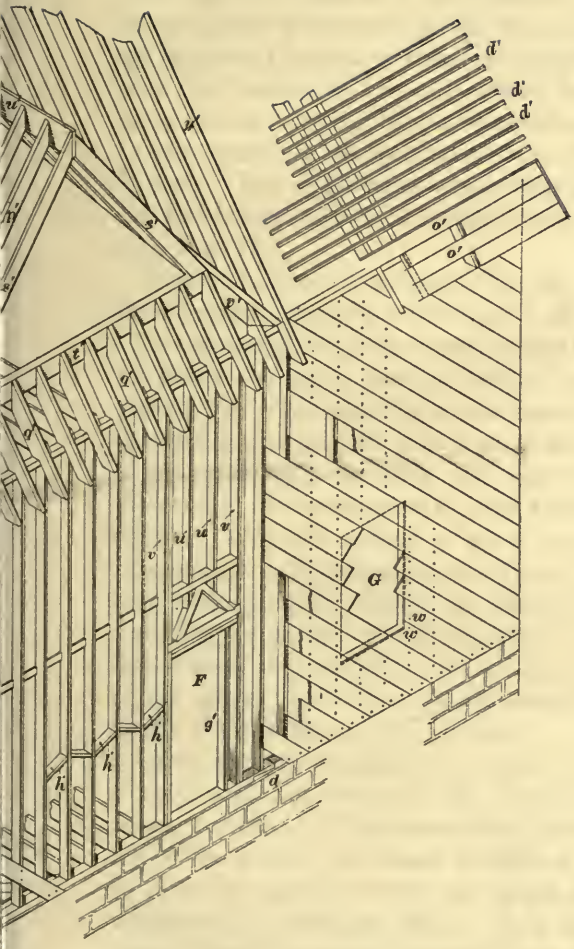
170. Balloon framing, as heretofore explained, is the term given to that system of construction in which the skeleton, or framework, of a building is spiked together with butt joints, and depends almost entirely for its strength and stability upon its exterior covering and the manner in which this covering is applied.

We will now take up the construction of a balloon-frame building, applying, as we proceed, such methods and means as have already been set forth in these pages, and studying, as they appear, such new or additional features as the necessity or the economy of the construction demands.

171. In Fig. 72, *A* is the stone foundation wall, 1 foot 6 inches in thickness. On top of the foundation wall is spread a bed of lime mortar at *c*, in which the sill *B* is laid and well bedded by means of repeated blows from a heavy hammer. When this is done, the outside edge of the sill, which is kept back 1 inch from the face of the wall, is pointed up; that is, the joint between the sill and the top of the wall is carefully scraped off to give it a neat, even finish, and any surplus mortar is removed from the 1-inch projection of wall. The plate is halved and spiked at the corners in the manner described in Art. **82,** as shown at *a* and *b*, and where the pieces composing it cannot be obtained in sufficient lengths, the sill is pieced out by means of the beveled splice, as shown at *d*. In exposed situations where high winds are frequent, it is not uncommon to anchor the sill to the wall by means of anchor bolts. These bolts are from 1 inch to $1\frac{1}{2}$ inches in diameter, and are firmly built into the mason work of the wall with the thread end projecting above it. Holes are then bored in the sill to fit over these projecting ends, and, after the sill is laid and leveled, it is securely held in place by screwing nuts tight on the ends of the bolts with a washer between each nut and the sill.



FIG


d'
d'
d'
o'
o'
G
w
w
F
g'
h
h
h
d
A

172. After the sill is set in its place, leveled, and its angles squared to be absolutely true, we may proceed to lay the first tier of floorbeams. These are notched over the sill to bring their tops to a level line, as shown in Fig. 30, or, where great economy of material is to be desired, the beams are notched 4 inches or more to bring their under sides flush with the bottom of the sill, where they are bedded in the same mortar topping of the foundation that the sill itself is, or the beams are blocked up on top of the wall with pieces of slate. But in all cases where they are so deeply notched *the floorbeams must have a solid bearing on the wall*, as shown at *e*, Fig. 72.

Where the span is so great that the beams must have an intermediate support, a brick wall, or a girder, as shown at *C*, is carried through the center of the house and is supported on posts. A brick wall is better for the purpose than a girder, for, when built up to the same height as the foundation walls, and capped with a wood sill of the same thickness as the main sill, we have the same amount of shrinkable material in all the supports of the first-story beams and partitions. Where a girder is used, however, we must take precautions to equalize, as nearly as possible, the effect of its shrinkage with that of the main sill. This is done by notching the girder, as shown, and by notching the beams in the same manner as at the sill, so that the solid portion of the girder below the notches is equal in thickness to the depth of the main sill of the house.

Great care is required in cutting these joints to insure a good seat, not only for the beam on the bottom of the notch, but also for the projecting tenon of the beam on the top of the girder; too much weight on the notch would tend to split the girder, while too great a strain on the tenon would tend to split the beam. It is for this reason that in strictly first-class work the beams are simply sized over the main sill, and their inner ends are similarly sized over an interior sill supported on a brick or stone wall.

Whether they meet on a girder or wall, the ends of the beams should be butted together, and held by cleats nailed

on each side; they should never be lapped one beam on the side of the other and spiked together, as this produces irregularity in the beam spacing, and makes the subsequent laying of hot-air pipes, etc. very troublesome. The floor-beams having been spaced and securely nailed along sill and girder at the uniform distance of 12 inches or 16 inches on centers, they are then cross-bridged, as shown at *f*. See Art. **109.**

173. While this bridging is in progress, or even before it is commenced, the side walls of the building are started, by setting the corner posts *a a'* and *b b'* in position. And after they have been carefully plumbed with a level and straightedge, as shown at *D*, or preferably by a long plumb-rule and blumb-bob, they are braced in position by two pieces of sheathing nailed securely to the posts and to the sill, as shown at *g*.

The corner posts are generally composed of two pieces spiked together, as shown at *a b'*, in Fig. 37, and the larger piece is sometimes, though not always, mortised or doweled into the sill.

174. After the corner posts are secured, the studs are spaced along the sill 16 inches on centers and are spiked both to the sill and to the floorbeams; they are then plumbed and carefully alined along the outside edge of the sill, and secured in place with braces similar to those of the corner post, those on the exterior being permanent in the form of sheathing, while the brace extending from the side of the stud to the floorbeam is but a temporary affair, to be removed as soon as the interior partitions and the second-story beams are in place.

These studs and corner posts are all cut to an even length on the ground before they are set in place, and at the same time the notches for the ledger boards *k* are cut in the studs 4 inches wide and 1 inch deep, and as soon as the studs are set in place, the ledger board itself is fitted and spiked to each stud with two nails.

On this ledger board the floorbeams *n* of the second story

are laid, each beam being slightly notched at *i*, on its under side, in order to bring the tops of the beams to an even alinement. The second-story beams are not nailed to the ledger board, but are securely spiked to each stud, on the same side of the stud as the beams in the tier below.

175. The beam shown at *j* is double the thickness of those at *n*, as it is a trimmer beam and carries the header *l* and the weight from the tail-beams *m*. This header and trimmer forms one end of the stair well, or opening, and if there is to be a similar opening in the third, or attic, floor, great care must be taken to place the attic-floor header perfectly parallel and plumb over this one, as trouble will arise when the stairs are built unless such care is observed.

176. The second-story beams being laid, we may now start the tier above, but if this third tier is simply to be of ceiling beams, and the attic story is not to be finished off in rooms like the rest of the house, we will first lay the wall plate *o*, which is usually composed of two pieces of studding nailed together and so lapped that the joints of any two lengths are as far apart as possible.

This plate is laid along the top of the wall and securely nailed to each stud; the attic beams are then notched over it in the same manner as the first tier of beams was notched on the sill, and securely nailed in place.

Our exterior frame is now fairly complete from sill to plate; and while the above described work has been in progress, the partitions have been erected, the first, or rough, floors laid on the interior, and the window and door openings framed, and the frame sheathed in, on the exterior. In fact, it is sometimes necessary to erect the main partitions at the same time as the outside walls, in order to provide a support for the interior ends of the floorbeams.

177. The studs *q q*, supporting the partition plate *r*, show the position of a principal partition which supports the ends of the second-story beams *m* and *n*, and the continuation of this partition in the second story supports the interior ends of the attic beams *p*.

The plate *r* on the top of these stud partitions is generally composed, like the main wall plate *o*, of two pieces of studding nailed together, and though one thickness would be strong enough for all practical purposes, the two pieces are preferable in order to secure the same amount of shrinkable material under each end of the beam, and as the ledger boards on the outside are 4 inches deep, the plate in the interior is made 4 inches deep, also.

178. The *framing of the openings* is shown at *E*, where the studs on each side of the opening are doubled and spiked securely together to act, practically, as one piece. The head and sill of the opening, if it is a window, are also composed of doubled studs, and where the window is over 3 feet in width, the top should be trussed, as shown at *s*, and described in detail in Art. **129.** The double studs at the sides of the opening are carried through to the plate, and if there are to be two openings, one over the other, the upper one alone need be trussed, unless there are floorbeams, or other details, which will concentrate too much weight over the opening. This is the case at *E*, and the window head is trussed to carry the load of the two beams *t* to the double studs at the sides.

179. In laying out the studding of the exterior walls of a building, two methods are used; one where the double studs at the sides of the doors or windows are first placed in position, and the single intermediate studs are spaced 16 inches on centers between them; and the other method, in which the studs are spaced throughout at the uniform distance of 16 inches on centers, after which the door and window openings are sawed out and the studding framed to suit.

The former of these methods is shown at *E* and the latter at *F*, where two studs *u u* have been cut out and the adjacent ones *v v* have been doubled, the space between them being trussed to carry the floorbeams in the same manner as at *E*. This leaves an opening of 4 feet between the centers of the studs at the sides of the opening, and, as this is more than

we require, we limit the opening by the stud g' cut in between the truss and the sill; or, if the plan requires the door to be further to the right, we can cut in two studs and center the opening at any point desired.

180. **Sheathing** is composed of $\frac{7}{8}$-inch boards, matched or unmatched, and planed on one side to give them a uniform thickness. In balloon-frame buildings *they should always be laid diagonally*, as it is upon the bracing effect of the diagonal sheathing that the building depends for its strength. When the corner posts of a building are set and plumbed, two pieces of sheathing are then nailed on its adjacent exterior sides with their lower ends spiked to the sill, as shown at g, and as the studs are successively set they are braced on the outside by similar sheathing boards, and every sixth or eighth stud is braced temporarily from behind, as shown at h. The sheathing is then carried over the whole side of the building, no attention being paid to door or window openings, except where a sheathing board projects a few inches over an opening; it is permitted to remain so, and the next board to it in the course is started from the other side of the window.

This is illustrated at G, where the dotted lines show the outlines of the window opening, and the full lines indicate the sheathing boards as they are laid up on the studs, to each one of which they are nailed with two tenpenny nails. At w is shown the sheathing sawed out to fit the opening, the boards being cut flush with the face of the studs.

181. When the sheathing is nearly completed and the first, or rough, floors are laid, the structure is ready to receive the first timbers of the roof.

The pitch of the roof in this case is rather steep, being 17 inches rise to 12 inches run, and the plumb-cut of the rafters will be found by laying the steel square on the side of the timber with 17 inches of the blade and 12 inches of the tongue on the line of what is to be the top edge of the rafter; the outside line of the blade will then mark the plumb-cut, as explained in Art. **153.** The foot-cut and overhang for the eaves are measured and cut as explained in Art. **153,**

and when one rafter is finished and sawed complete, it is used as a templet to mark and cut all the others by, before the framing of the roof is commenced.

The first rafters set are those forming the end of the gable at x, and the ridge plate z is composed of a wide piece of $1\frac{1}{8}$-inch material beveled on its upper edge, as explained in Art. **164.** To this ridge plate the rafters x are spiked on opposite sides, and somewhere near the other end two other rafters are similarly spiked to hold the ridge plate in position. The rafters y and y' are so placed as to foot on the plate o adjacent to the valley rafters w' and v', which are then placed in position, having been previously cut to the required lengths. The valley rafter w' is set first, and then the valley rafter v' is securely footed on the plate and spiked against it. The header plate t' is then spiked between these two valleys at the point where the slope of the smaller gable is to start, and after t' is securely nailed to the two valley rafters, the first two of the small gable rafters s' may be set in position, securely nailed to the header plate t' and spiked through the ridge plate u', whose other end is nailed into the angle formed between the two valley rafters w' and v'.

The ridge plates z and u' and the header rafter t' must, of course, be perfectly true and level, and when set they must be so securely fastened that subsequent operations will not force them out of line. The jack-rafters r' and p' may now be set in pairs, one each side of the valley rafter w'. This is done in order that the thrust may be the same on each side of the rafter at the same time, for, if we laid all the jack-rafters on one side at the same time, it would cause the valley rafter to bulge and curve out of line and prevent the opposite rafters from fitting properly.

For this same reason great care must be exercised in setting the jack-rafters q', as, in driving them close into their places, we are apt to cause the header rafter t' to bulge inwards, and out of line with the gable rafters s' above.

182. After all the rafters are in place, the boarding of the eaves is laid, as shown at o', and above this boarding

the shingle laths *d'* are laid, with a clear space between them equal to the exposed length of the shingles. The spacing of the shingle laths is measured from the lower edge of the lowest roof-board at the eaves, and the spaces are measured off up the rafters to the ridge, where any difference in exposure of shingles can be taken up by increasing, or slightly diminishing, the width of the ridge boards when they are laid. Side sheathing, roof sheathing, and shingle laths must be nailed to each stud, or rafter, with two nails for boards and one nail for shingle lath; where a joint occurs in a length of board, or shingle lath, it must be in the center of the rafter, or stud, and both joining ends must be securely nailed to the supporting timber.

183. The rough framing of the building may now be considered as complete. The skeleton is up and covered in with its sheathing; the floorbeams, or joists, are in position, and the rough, diagonal flooring is laid; the partitions dividing the interior are all studded, and the openings for doors and windows have all been framed and sawed out through the sheathing.

It now remains for the carpenter to lath the partitions, cross-fur and lath the ceilings, nail on the grounds which are to secure the wainscot, trim, picture moldings, etc., on the inside of the building, and to set the frames for the windows and doors, apply the outside casings, put on the clapboards, or siding, and shingle the roof on the exterior of the building; his work will then be practically complete, until after the joiner and painter have finished. In many localities, lathing is executed either by special lathers or by plasterers.

184. Before the walls are lathed, it is sometimes desirable in buildings where the ceiling is high, to provide a line of bridging between the studs, as shown at *h'*; the bridging tends to make the walls stiffer sidewise, and the studs are thus prevented from warping.

At *f'* is shown a filling of *brick nogs*, as they are called, from the top of the foundation wall to the top of the beams.

This nogging consists of pieces of old or broken bricks, laid in lime mortar so as to completely fill the spaces between the studs and up to the top of the beams, as shown at *a*, Fig. 73, thus closing not only a passageway for cold drafts from the cellar, but also against the rapid spread of flames in case of fire. The brick nogging may, with advantage, be continued up three courses higher than the beams, between the studs, which will prevent drafts at the floor level, caused by the circulation of the air through the channels between the studding. Sometimes, where brick is not convenient, short pieces of $2'' \times 4''$ studs are filled in and spiked to the sill and beams.

VARIOUS DETAILS OF CONSTRUCTION.

PLASTER GROUNDS.

185. Plaster grounds, as explained in Art. **123,** are simply nailing strips secured to the studs for receiving the trim; they consist of strips of wood from $\frac{5}{8}$ inch to 1 inch in thickness, according to the character of the plastering, and in width they vary from 2 inches to 3 inches, according to the purpose they are to serve.

In the angle formed at the meeting of the stud partitions and the rough floor, a strip 1 in. $\times$ 2 in. is nailed to the studs, and a similar strip is nailed about the height of the baseboard above and parallel to it. To these strips the base is then nailed after the plastering is dry.

In dining rooms, kitchens, billiard rooms, etc., where a chair rail, or wainscot, is to be placed, another ground about 4 inches wide, is nailed to the studs 2 feet 6 inches to 3 feet above the floor, according to the height of the wainscot, and in parlors, libraries, reception rooms, etc., a strip 1 inch in width is nailed from 1 foot to 2 feet 6 inches below the ceiling to receive the picture molding. This latter strip is not generally used, as the picture molding may be placed directly on the surface of the plaster, wire nails being driven in the studs or furring strips, or into wood plugs in case of brick

partitions. Where a wood cornice is to be carried around a room, a ground must be provided for it in the angle between the ceiling and the side walls.

The surface of the stud partitions between these grounds are then lathed. The ceilings in ordinary work are lathed directly on the under side of the beams, but where a first-class job is desired, the beams should be cross-furred, as explained in Art. **126.**

186. The interior of the house is now ready for the plasterers, but the carpenter should shingle the roof before the plasterer's work is started, in order to protect the walls and ceilings in case of rain. The shingling should be started as soon after the roof is covered in as is possible, and according to the methods previously explained.

SIDING.

187. **Siding** is the term which is applied to the material with which the exterior walls of a frame building are usually covered. There are two kinds, the *beveled* siding, and the *novelty*, or *patent*, siding. The former consists of sawed and planed boards in commercial lengths of about 16 feet and a width of from 4 to 6 inches. Its thickness is $\frac{5}{8}$ inch at one edge, beveling back to $\frac{3}{8}$ inch at the other edge, as shown at Fig. 73.

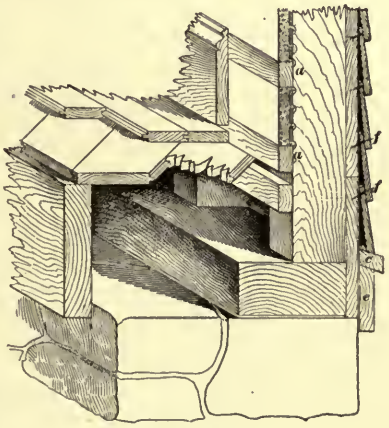


FIG. 73.

Novelty siding has a uniform thickness of about $\frac{7}{8}$ inch, except where it is rabbeted at the bottom to receive the chamfered edge of the next board below it, and where it is chamfered at the top to fit the rabbet of the board next above

it, as shown at *b*, Fig. 74. Novelty siding is manufactured in single widths of from 5 inches to 9 inches, though in very cheap grades of work it is used in double widths, with a groove worked lengthwise through the middle to imitate the joint, as shown at *c*, Fig. 74.

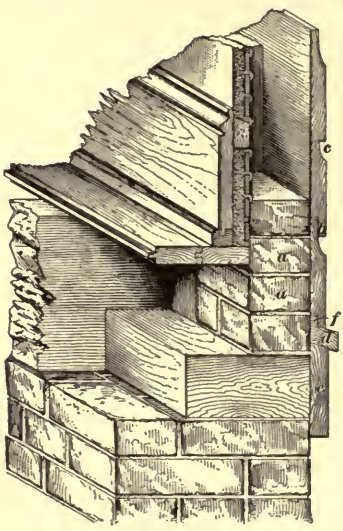


FIG. 74.

The depth of the rabbet and the width of the chamfer limit the amount of lap that can be made with novelty siding; whereas, with beveled siding, one course may overlap the other any distance within the limits of the width of the material. It is far preferable, therefore, to use the beveled stock on all first-class work, though it costs a trifle more and requires more labor to put it in place. It is more durable on exposure to the weather, less liable to crack and check, while its thinness renders it easily dried out, and the stock is much more liable to be well seasoned than that used for the novelty siding.

188. Before the siding is put on the building, the **water-table** *e*, Fig. 73 and Fig. 74, is placed all around the structure about 1 inch below the sill. The water-table has a pitched cap, shown at *c* and *d*, which serves the purpose of receiving the water which runs down the side of the house and shedding it off to the ground before it works its way into the foundation, to rot the sill and render the house damp and unhealthy.

The cap of the water-table is beveled in order to give its top surface an inclination of from 15° to 30° from the horizontal, and it has a tongue worked on its top to form a seat for the lower piece of siding and make with it a water-tight joint, as shown at *f*, Fig. 74.

189. Over the sheathing of the building, from the water-table to the plate, is laid one or more thicknesses of heavy felt, or resinous building paper, to prevent drafts from working through the cracks and joints; and over this paper, and above the water-table, the siding is laid in horizontal courses, each course being nailed through its lower edge, as shown at *f*, in Fig. 73. Cut nails $2\frac{1}{2}$ inches long and having flat heads, should be used, the siding being nailed *only* at the studs and the nails set in, so that they may be puttied over. Beveled siding should be carefully gauged as to lap, so that the edges may be made to run in line with the horizontal lines of the window and door trim.

190. Circular Siding.—When a circular tower, or semicircular bay window, exists in a building, it is necessary to prepare the siding with its lower edge convex and its upper edge concave, in order that these edges may lie in horizontal lines when the siding is bent around the curved front of the tower. Fig. 75 shows the elevation (*a*) and the plan (*b*) of a portion of a circular tower, the siding of which must be worked with curved edges, as shown at (*c*). To find the radius and extent of this curvature the axial line *d e* is drawn through the center of the tower and prolonged towards *e* indefinitely. The line *o s* is then drawn as a continuation of the direction, of the inside slanting surface of one piece of the siding; *o s* is prolonged until it intersects the axial line *d e* at *x*, and with *x* this point of intersection as a center, and radii equal to *x o* and *x m*, respectively, the arcs *o p* and *m n* are described. Then the

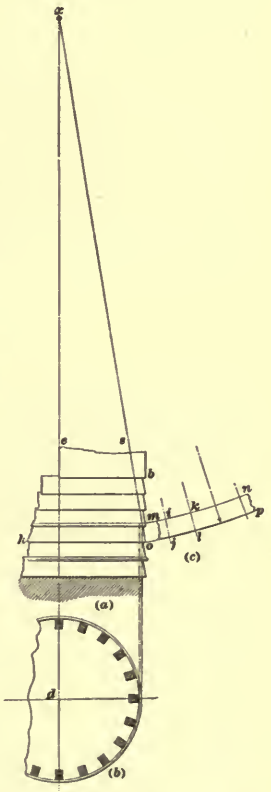


FIG. 75.

figure *m n p o* will be of the form and curvature necessary to secure the level lines on the top and bottom of the siding after it is bent around the tower in the position shown at *o h*.

This form *m n p o* should be first cut out of heavy paper, and then, using the paper as a pattern, the curve can be traced on each strip of siding and worked out with a draw-knife and plane. The exterior distance from center to center of the studs shown in the plan (*b*) should be marked off on the pattern piece with lines converging towards the point *x*, as shown at *i j*, *k l*, and all the butt joints between the ends of two pieces of curved siding should be cut on one of these lines, in order to insure a properly fitting joint and to have the ends meet in the center of a stud. When the siding is put on the building, its lower edge is laid and nailed to a line previously marked for it over each stud.

Where the siding is specially worked with a vertical back, so as to hug the sheathing, it can be applied in straight pieces; in this case, the surface of the tower is *cylindrical*, while in the other it is *conical*.

VERANDAS.

191. The details of the construction of the exterior features of a building require, on account of their exposed situations, especial consideration in order to insure the fulfilment of the purposes required of them.

Veranda construction must provide all the requirements of an out-door sitting room in fair weather, and at the same time insure the side of the house on which it is built against the invasion of water and dampness during a heavy rain storm, and effect the rapid drying of the floor and timbers after such a storm is over.

192. Fig. 76 is a perspective view of the details of veranda construction shown in drawing plate entitled, Constructive Details, *Architectural Drawing*. The floor *d* pitches at the rate of $\frac{1}{4}$ inch in a foot from the house line to the front edge at *e* in order to drain the water off as soon as it

falls. For the same reason the boards of the floor are laid across the veranda, as shown, as the water would otherwise lodge in the joints and soon rot out the material.

In order to run the floor boards in this direction, it is necessary to provide means of framing the floorbeams lengthwise of the structure. Therefore, under each veranda post is built a brick or stone pier *a*, on which is laid the $4'' \times 6''$ sill *f* extending full length of the veranda, and from this

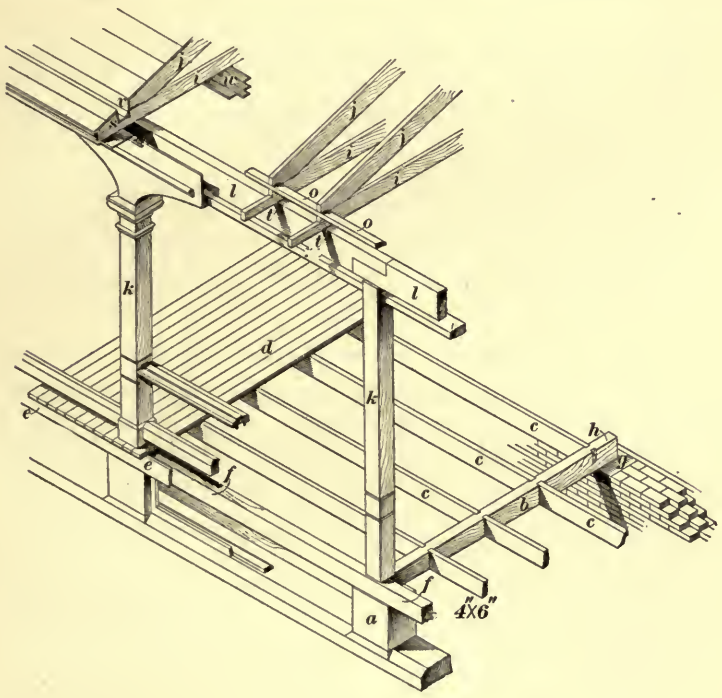


FIG. 76.

pier a girder *b* extends to the foundation wall of the house, where a stone templet *g* is built in to receive it; or, where the veranda is narrow, the girder simply rests on the brickwork without any templet. The veranda floor joists are then framed into the girder, as shown at *h*, and securely

spiked in place. In frame buildings the girders usually rest on a ledger board, well spiked to the sheathing.

In order to secure the necessary pitch of $\frac{1}{4}$ inch to a foot for the veranda floor, the girder *b* may be laid at the necessary inclination; or, its top may be planed, or sawed, down so that it has the proper pitch and the bottom remain level. In either case, the beams are framed so that their tops are flush with the top of the girder, and the flooring is laid directly upon them.

193. Veranda *flooring* should be at least $1\frac{1}{4}$ inches in thickness, tongued and grooved and laid in white lead; that is, the joint between two boards should be thoroughly filled with a pasty composition of white lead dissolved in raw linseed oil. This is accomplished by coating the edges of the boards with the mixture and driving them tightly together as they are laid. A good material for veranda floors is clear, dry white pine, heart stock, and free from all imperfections.

194. Veranda *posts*, whether square, as at *k*, or turned in a lathe, should be selected of good, sound, dry timber, which is the heart wood of the tree. After being sized to the required dimensions, they are carefully sawed squarely across the ends to an even length, the pores of the lower end of the wood are then filled with white lead, and the post is stood on the finished floor of the veranda. A girder *l* connects the upper ends of these posts and serves to support the ceiling beams and rafters *i* and *j*. On the ceiling beams *i* the plate *o* is spiked, and the foot of the rafters *j* is notched out to fit over it, as shown.

The inside ends of the beams and rafters are notched over a ledger board in the same manner as second-story floor-beams, where the building is of frame, and in brick or stone walls, they are built in and anchored, as described in Art. **108.**

195. The roof, which pitches at the rate of 4 inches in a foot, will be boarded over with matched roofing boards and

then covered with tin, as the inclination is too flat for shingles or slate. The gutter is formed by cutting out about one-half the depth of the projecting portion of the ceiling beams, as shown at *t*, and sawing the lower end of the rafters to stand plumb over the girder *l*. The continuation of the roof pitch below the gutter is then maintained by spiking to each ceiling beam a triangular piece *s* and boarding it over to form the roof slope and gutter *v*.

The ceiling of the veranda may be formed with narrow strips of pine, or hardwood *w*, laid on and blind nailed securely to each of the ceiling beams *i*. A better appearance is presented when the ceiling boards are placed at right angles with the building, in which case blocking or furring strips would be run at right angles with the ceiling beams. Sometimes the veranda roof is left open on the under side, exposing the timber construction. When this is the case, no ceiling beams are used, but the rafters are planed and dressed on their under sides, and the roofing boards are of selected, narrow stock, planed and matched, and laid with their finished sides downwards.

196. **Chamfering** is sometimes resorted to as a means of relieving exposed timbers of the sharp angle or corner where their finished faces meet. It consists of cutting off the corners of a girder, ceiling beam, veranda post, or other exposed timber, for a part of its length, and stopping the *chamfer* against an oblique cut made at an angle of about 45°, as shown at *a b* in Fig. 77, where *b c* is one of the chamfered corners of a square post.

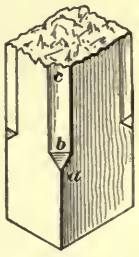


FIG. 77.

197. Chamfered corners are very conspicuous in Swiss cottage architecture, where the entire framework of the building is more or less exposed and ornamented. The depth or breadth of a chamfered edge is entirely a matter of taste. Of course it should never be so deep as to impair the strength of the timber, while, on the other hand, it should be prominent enough to be clearly

seen from any point where the timber so treated is conspicuous. This is especially the case with girders and floorbeams, which, being above the eye, require a somewhat heavier chamfer than posts and railing, which are lower down and more closely observed.

CENTERS FOR ARCHES: DOMES.

198. Centers.—Where any portion of the outer or inner walls of a building are of brick or stone, and the openings in these walls are circular headed, the carpenter will be called upon to make wooden templets, or **centers,** as they are called, and set same in place for the mason to lay the stones or brick of his arch upon until the mortar has thoroughly set and rendered the arch self-sustaining.

199. In Fig. 78 is shown a wood center for a semicircular window in a 12-inch brick wall; (*a*) is the side view of the

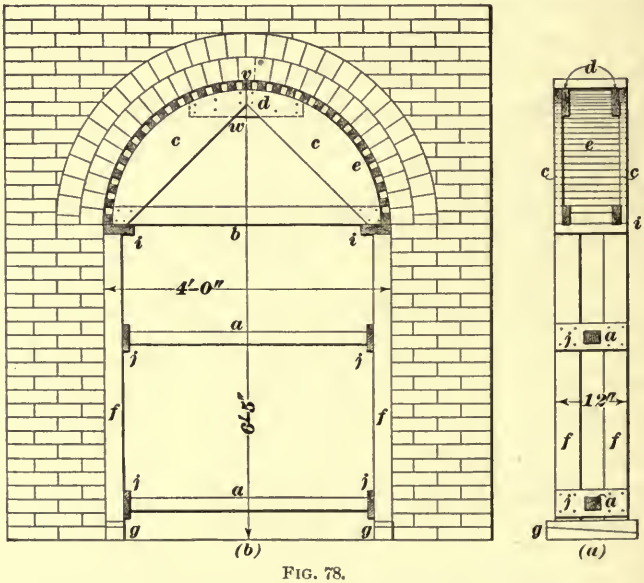


FIG. 78.

center and its supports, and (*b*) the elevation of the center in position in the wall. The faces of the center are, in this

case, each composed of two pieces *c* of 1¼-inch plank sawed to the proper curve and secured at the bottom by the tie-piece *b*, which is securely nailed to each of the face pieces *c*, *c*, while the joint at the top is secured by the fish-plate *d* nailed to both pieces on the inside of the boards.

Two of these face pieces having been thus formed, they are joined together with small strips, called *lagging*, 1¼ inches thick, 1½ to 2 inches wide, and 12 inches long, as shown at *e*. The bottom of the face pieces is secured by two *caps i* nailed to each face, under which the supports *f* are placed, when the center is set in the opening ready to be built upon. The lower ends of the supports *f* do not rest directly on the sill of the opening, but upon two slip wedges *g*, which are gradually driven out after the masonry has set, thus allowing the arch to gradually settle down to its own proper bearing. The braces *a*, *a* are inserted between the cleats *j* to maintain the supports in a vertical position against the jambs of the opening. All wood arch centers may be framed very nearly in this same manner, except in very large spans, where heavier timbers must be used.

200. Elliptical centers are formed in the same manner as those for circular arches, but usually require more pieces in the curved faces. For this reason it is advisable to lay out, on paper, a semiellipse of the required height and span according to the method described in problem 24, *Geometrical Drawing*, and with this paper form lay out the curved line on the several pieces of plank which have previously been arranged to occupy about their proper position in the finished center, as *a*, *b*, *c*, and *d*, Fig. 79. The curved edge is then sawed out on each piece separately, the ends are then sawed to the proper miter line, and fish-plates are nailed on the back in the same manner as *d* was nailed on *c*, in Fig. 78. When great strength is required, it is sometimes advisable to make these fish-plates as large as their face pieces *a*, *b*, *c*, *d*, and miter their ends to an even joint, as shown in Fig. 79. The ends are secured in place by the tie-pieces *f* and the caps *g*, while the center is strengthened by a strut *e* extending

from the tie-piece *f* to each of the intermediate sections of the face pieces, as *b* and *c*. The small $1\frac{1}{4}'' \times 2''$ strips are then nailed on the curved edges in the same manner as for

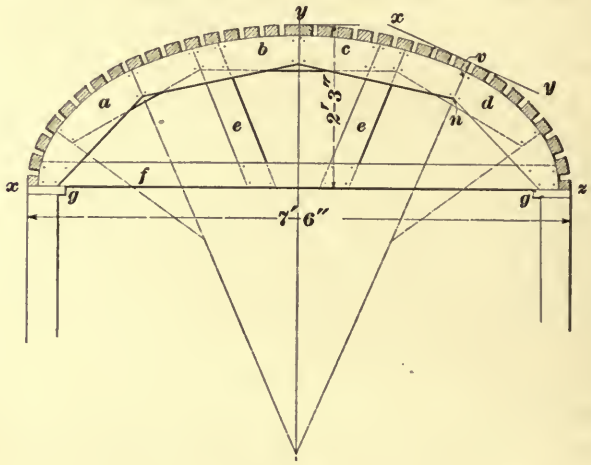


FIG. 79.

the semicircular center, their length being equal to the thickness of the wall in which the arch is to be built.

201. In all wood centers the joints between the different sections of the face pieces should always be in a line perpendicular to a tangent at the point where the joint line intersects the curved line of the arch; that is, in Fig. 79 the joint line *n v* is perpendicular to the line *x y*, which is tangent to the curve at *v*. These joint lines will all converge towards the center from which the curve is struck when the arch is semicircular, as *v w*, in Fig. 78, but in other curves they can be found only by first drawing the tangent, as in Fig. 79.

202. **Trimmer-arch centers** are built to extend from the brick wall of a chimney to the header beam of the floor, where it is framed around a fireplace, as shown in Fig. 80.

A characteristic difference between the trimmer-arch center and those previously described, is that the wood center is generally left in place and remains in the building after the masonry arch is laid over it. When the mason builds the brickwork of the chimney he corbels out one course of brick about $1\frac{1}{2}$ inches at the level of the under side of the floorbeams, as shown at *e*, and the carpenter builds his center to have one end rest on the brickwork at *e*, and the other end notched over a $1\frac{1}{2}'' \times 2\frac{1}{2}''$ or $3''$ cleat *d* nailed on the header beam *a*. The face piece of the center *c* is $1\frac{1}{4}$ inches in thickness, and its upper edge, on which the

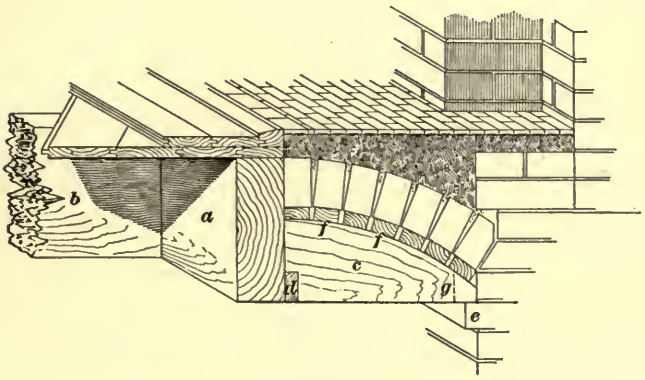


FIG. 80.

lagging *f* is nailed, is sawed to the curve of the arch so that the small end will be about $1\frac{1}{2}$ inches in thickness where it rests on the brickwork at *e*, and is about $4\frac{1}{2}$ or 5 inches less at the large end than the depth of the floorbeams. The number of pieces like *c* required for a trimmer-arch center depends on the length of the hearth which is to be built over it; but if the ceiling below is to be plastered, it is desirable to have one in front of the end of each tail-beam where it mortises into the header, in order to simplify the lathing.

Sometimes the lathing can be more readily accomplished by nailing a filler piece between the face pieces *c*, as shown by the dotted line at *g*, and then running the lath strips from

the filler g to the nailing cleat d; but, unless the hearth is a very long one, the former method will be found most satisfactory.

203. When the roof of a building is carried up, either wholly or in part, in the form of a hemisphere, or semi-ellipsoid, it is called a **dome,** and the rafters supporting it must be sawed or bent to the required curvature.

204. A **hemispherical** dome is shown in Fig. 81, in which (b) is a half plan, and (a) is the sectional elevation. The curve of the dome is described from s' as a center with a radius $s'\,c'$. This is also the curve of the outside of the rafter. The center of the plan s is the point from which the curved outline of the plate a is described, on which the feet of the rafters f rest. At c is the upper plate, which receives the upper ends of the rafters f, and at the same time forms a circular opening, called the **eye** of the dome, which admits light and ventilation. About half way up the curved outline, at b', is shown a line of purlins cut in between the main rafters to receive the upper ends of the small jack-rafters g. This line of purlins is shown at b in the plan, and it is at about this point that the main rafters are spaced at a uniform distance of from 16 inches to 24 inches apart, the jack-rafters being then

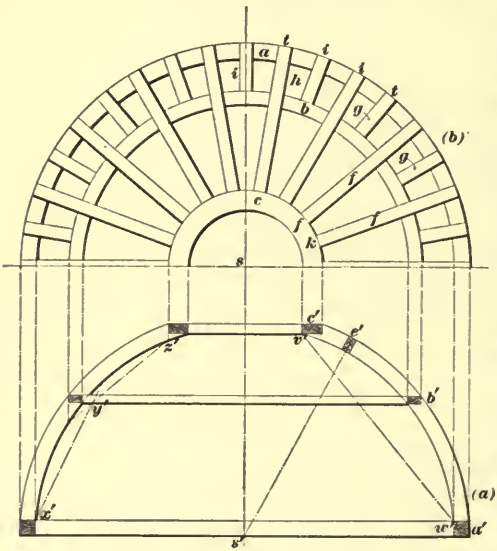


FIG. 81.

inserted between their lower ends and spiked to the plate *a* and the purlins *b*.

The method of forming, or building up, the plate *a* is the same as described for the conical roof in Art. **144,** and the rafters are bent, or sawed, in the same manner as the curved rafters of the ogee roof, described in Art. **148.** Where bent rafters are used they are composed of thin strips bent over a form, each layer being nailed together. When the dome is for exterior effect only, and the inside is not to form part of any particular room, the rafters need not be sawed to a curved line on the under side, but may retain the straight edge of the board from which it is sawed, as shown by the dotted line $v'w'$, or, if composed of two pieces, by the lines $x'y'$ and $y'z'$.

205. There are two methods of boarding over the curved surface of this dome. The first method is shown in Fig. 82, where *n o f* is the outline of the curve of the plan of the dome, and *a b* is the outline of the curve of the elevation. From *c*, the center of the plan, we draw the line *c d* of indefinite length, but at right angles to *c b*, the axis of the elevation, and at *e r* on the plan, we lay off the width of one of the roofing boards, *o e* and *o r* being each equal to one-half the width of a board; the lines *e c* and *r c* then represent this board in place on the plan. The line *a b* is then divided into any number of equal parts, the points of division being marked *s*, s', s'', etc., and these parts are then laid off on *c d* from *o* so that *o d* represents the length of the line *a b* folded out straight, and *o f*, $o f'$, etc. are each equal to *a s*, $a s'$, etc. From *s*, s', etc. we now draw perpendiculars through *c o*, cutting *c e* and *c r* at *l*, l', etc. From the points *f*, f', etc., on the line *o d*, draw lines at right angles thereto, and make *t f* equal to one-half of *l l*; $t' f'$ equal to one-half of $l' l'$, etc. A curved line drawn through the points *t*, t', etc., to t^{vi}, will be the outline of the **gore,** or covering board required, and if this be laid out on a sheet of heavy paper and cut to the lines, it will form a templet, by which all the boards may be marked and cut. To support the

gores curved purlins as shown at e', Fig. 81, are inserted between the rafters. These purlins are spaced to suit the curvature. A conical roof, such as is shown in Fig. 55, is also boarded in this manner, and small purlins must there, too, be framed in between the rafters to receive the board-

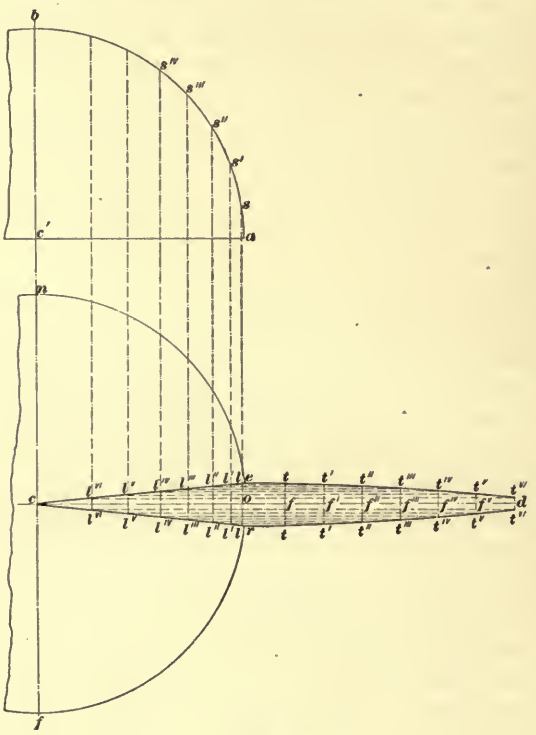


FIG. 82.

ing. The boarding of the conical roof, however, requires no curvature, but simply tapers from the plate towards the apex in a straight line.

206. A second method of covering the dome is shown in Fig. 83. The boards in this case are laid in short horizontal courses. One-half the elevation $a\,e$, Fig. 83, is divided into any number of equal parts, $a\,b$, $b\,c$, $c\,d$, etc.,

each part being equal to the width of one of the covering boards; the line *b e* is drawn from the point *b* through the point *c* and is prolonged until it intersects the axis of the dome prolonged at *h*; then from the point *c* through *d* a line is drawn until it intersects the axis line at *j*, and so with each of the other parts, until we get the points *k l m*, etc., on the axis line. With *h* as a center and a radius *h b*, we can now describe the curve which will form the lower edge of the board *b c*, while with the same center and a radius *h c* we describe the arc *c p*, which marks the curvature of the upper edge of the board. From the point *j* as a center, and with the radii *j c* and *j d*, we describe the arcs *c t* and *d u*, which mark the outline of the board *c d*, and in the same manner for each of the boards in the dome, until the top opening, or eye, is reached, which, when not to be framed, is closed over with a flat, circular piece of board, the center of whose curvature would be at *e*.

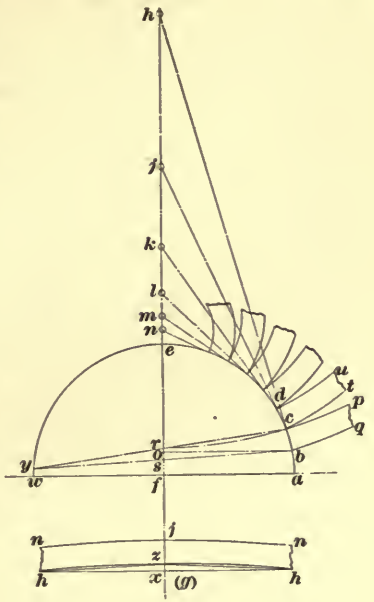


FIG. 83.

207. When a dome is comparatively small, and great neatness is required in the perfection of its semicircular outline, it is desirable that the joints should be planed down to round the surface, whether the boards run horizontally around the dome, as in Fig. 83, or extend from bottom to top, as in Fig. 82.

When a dome is large and well above the eye, as on the roof of a high building, such nicety is not required, as the covering material will round the form to the desired outline.

208. An **interior** dome is sometimes built under a flat roof, and is very commonly seen over a stair hall, which is illuminated through an ornamental glass skylight inserted in the eye of the dome. These interior domes are generally elliptical in form, but whether the outline is a semicircle or semiellipse, the method of framing is precisely the same.

Fig. 84 is the plan of an interior dome whose outline is an ellipse, with a length *a c* and a width *b d*. In its center is shown the eye, whose length *k g* and whose width *e f* are in

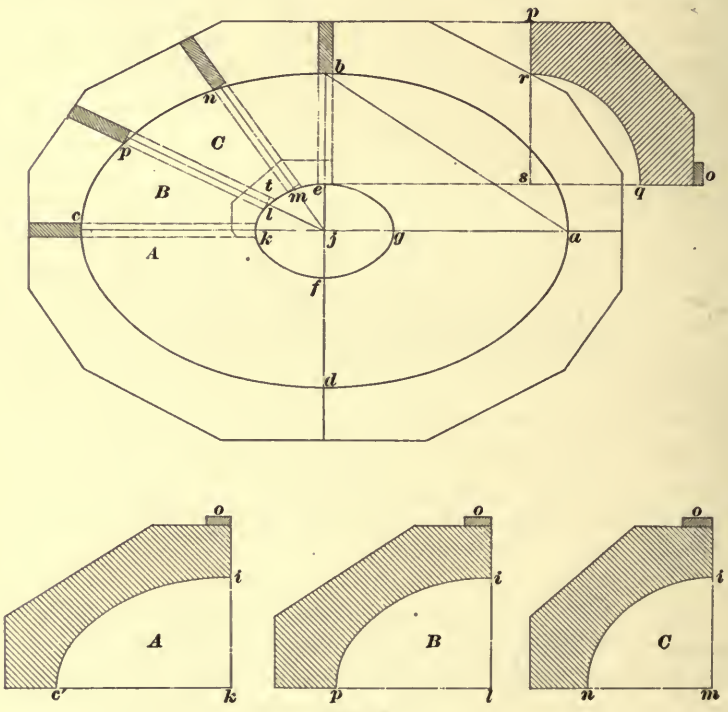


FIG. 84.

direct proportion to the length and breadth of the larger ellipse. The plan of the dome *a b c d* is formed by cutting the curved sides from separate boards and nailing these boards around the opening framed in the floor or roof over

which the dome is to be built. The eye of the dome is made of four or more pieces of board securely nailed together to receive the upper ends of the ribs when set in place.

There will be four sets of these ribs, each set representing one-quarter of the dome. The rib *b e* will have for its curve a quarter circle with a radius *e b*, as shown at *o p q r*, where the points *e* and *b* have been projected to *q* and *r*, and the arc *r q* has been struck from *s* as a center, with a radius *s r* equal to *e b*. The other ribs *m n*, *l p*, and *k c* have each the curve of a quarter ellipse, whose shorter semiaxis is, in each case, equal to the height of the rib *b e*, shown at *s q*, and their larger semiaxis will be the length of each rib in plan, as *m n*, *l p*, and *k c*. These ribs are shown at *A*, *B*, and *C*, the vertical heights *k i*, *l i*, *m i*, each being equal to *s q*; on each of them, is shown at *o* the section of the eyepiece *t*, which holds them in place. Such a dome as this should be lathed with wire lath, as it is impossible to preserve the curvature with wood lath.

209. A **groined ceiling** is formed by the intersection, or crossing, of two arched passageways; the framing required for it is shown in Fig. 85, where *A* is an arched passage 3 feet 8 inches in width, intersected by another arched passage *B*, 6 feet 4 inches in width. At *b f d* is shown the soffit of the arch over *A*, revolved on the exterior line of the thickness of its material to keep it clear of the other details, and at *b g c* is shown the soffit of the arch over *B*, revolved in a similar manner. The lines of intersection of these arched, or vaulted, surfaces are called **groins**, and they occur on the diagonals *a b* and *c d*, which intersect at *o*. If both passages were of the same width, both arches could be semicircular, as is the arch over *A*, but as *B* is much wider, and at the same time no higher, than *A*, the curve of the arch over *B* becomes a semiellipse, with its longitudinal axis *b c* equal to the width of the passage, and its semitransverse axis over the axial line of the passage *B* equal to the height *f q* of the semicircular arch over *A*.

The groins *a b* and *c d* will also be semiellipses, and their curvature and the necessary dimensions for the ribs may be obtained by erecting *o n* perpendicular to *a b* and equal in length to *f q*, and then describing the quarter ellipse *b r' m' n*, with *o n* as its semiminor axis, and *o b* as its semimajor axis. These ellipses may be described according to the method explained in *Geometrical Drawing;* or, points

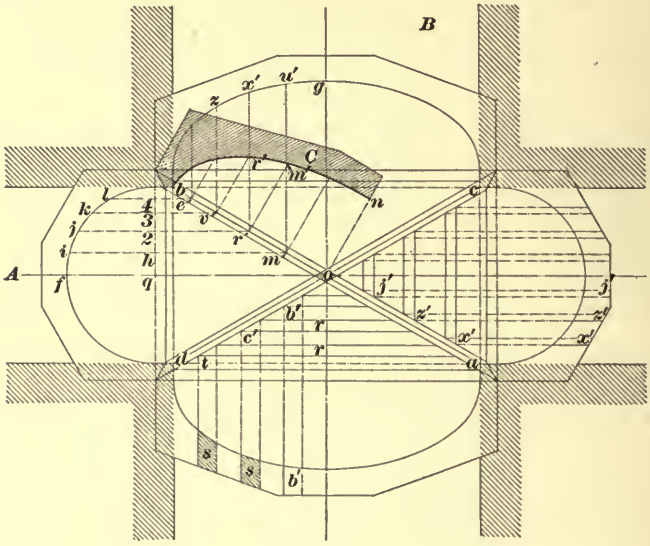


FIG. 85.

on the curves may be determined by projection. From any points on the circular arch, as *i*, *j*, *k*, *l*, draw the lines *i m*, *j r*, *k v*, *l c*, parallel to *o f*, and where these lines intersect the diagonal line *o b*, erect perpendiculars both to the groin and to the measuring lines. Then, by laying off successively on these perpendiculars the distances *i h*, *j 2*, *k 3*, and *l 4*, from *m*, *r*, etc. on the line *a b*, and from line *m'*, *r'*, etc. on the line *b c*, points will be established through which may be drawn the ellipses *b n* and *b z g*.

210. A pointed arch is one composed of arcs struck from two or more centers whose curves are not tangent to each

other, but meet at an angle, as shown at *f*, Fig. 86. The ceiling of two intersecting passages which are vaulted in the form of a pointed arch, or vault, forms a groined vault not unlike that just described.

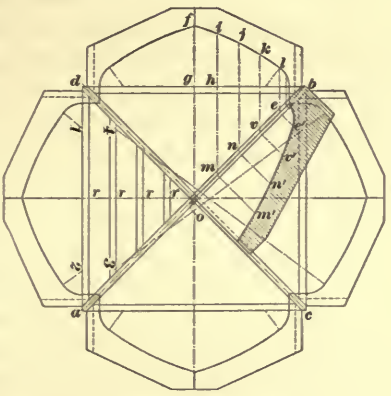


FIG. 86.

Between these intersecting groin ribs, small jack-ribs or rafters *r* are framed, and their curved outline is precisely the same as that of the main ribs *b g c*, Fig. 85, as far as they reach each side of the center, or axial, lines. The main ribs and jack-ribs are spaced from the center *o* at a uniform distance of 16 inches, or 24 inches on centers, according to the span, and lath is then applied in the usual manner to the under side.

The lengths and cheek-cuts of these jack-ribs may be determined by projecting their points of intersection with the groin ribs to the curve of the main ribs. Thus, from the points *j″ z′ x′* and *b′ c′ t* on the groin ribs *o a* and *o d*, Fig. 85, draw the lines *j″ j″*, *x′ x′*, etc.; the exterior lines of each rib will determine the length of the side of the jack-rib which is farther away from the point *o*, and the interior lines for each rib will mark the length of the jack-rib nearer the point *o*; then, if these lines are marked on opposite sides of the jack-rib, a line connecting their ends across the edge of the jack-rib will mark the cheek-cut, as shown for the two longer jack-ribs at *s*.

211. The pointed vault shown in Fig. 86 is composed of the arcs of two circles described from four centers, *1*, *2*, *3*, *4*, as shown by the radial lines. The smaller arcs at the sides of the vault, described from centers *1* and *2*, are tangent to the larger ones described from centers *3* and *4*, but these two last named arcs are not tangent to each other, and,

therefore, form a point at the center which is over the axial line of the passage. The diagonal or groin ribs are laid out, as explained in Art. **209,** by means of lines projected from points on one of the arches parallel to the axial line *f o*, and intersecting the groin line *a b*. Perpendicular to the groin at these points of intersection the lines *m m'*, *n n'*, *v v'*, and *c c'*, are drawn equal in length to *i h*, etc., respectively, and through the points *m'*, *n'*, *v'*, *c'*, the curve of the groin is described. The wooden rib, whose under side forms the contour of this groin, is shown by the shaded portion.

Between these intersecting groin ribs small jack-ribs *r* are framed, and their curved outline is precisely the same as that of the main ribs *d f b* as far as they reach on each side of the center line. The main ribs and jack-ribs are spaced from the center *o* at a uniform distance of 8, 16, or 24 inches, according to the span, and lath is then applied in the usual manner to the under side. The bevels for cutting the ends of the jack-ribs are found in the manner previously described.

212. Pendentives.—Another method of finishing the roof or ceiling over the intersection of two passageways, is to construct over the crossing a hemispherical dome, when the passages are of the same width, and an elliptical dome when they are of different widths. The effect of this treatment is shown in Fig. 87, where the passage *A* intersects and crosses the passage *B*, and the sides of each one, prolonged by dotted lines, forms the rectangle *a b c d*, which is the plan of their

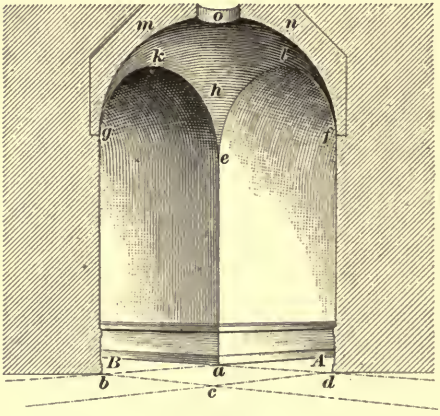


FIG. 87.

intersection. The roof of each passage is vaulted over with a semicircular arch, as *g k e* and *e l f*, while from the points *e*, *f*, and *g*, where these arches spring, there also starts a hemispherical dome *g m o n f*. The corners *e*, *f*, and *g* gradually round over to the eye of the dome at *o*, and at the same time broaden out in a fan shape over each of the adjacent arches, as seen at *e k l*.

This spherical triangle *e k l*, which brings the curvature of the dome down to the corner of the passage at *e*, is called a **pendentive,** and there is, of course, one of them over each of the corners *a*, *b*, *c*, and *d*.

213. To develop the curvature of the ribs and construct the frame work for the dome and pendentives, the plan of the intersecting passages is first drawn, as shown in Fig. 88, at *a b c d*; next, the axial lines of the passages *A A* and *B B* and the diagonal lines of their intersection, over which the ribs *v' a'*, *g g'*, *a c*, and *b d* are located, are drawn. Then with center *o*, and with a radius *o a*, draw a circle through the four corners of the plan *a b c d*; this circle will represent the plan of the dome. If this dome is now cut on the line *d c* at right angles to its plan, the section produced will be the semicircle *c e d*, which is the arch over passage *A*.

There will be four of these arch ribs, one over each of the lines *a b*, *a d*, *c b*, and *c d*, and that part of the dome which would extend into each of the passages, as at *a v d*, is cut off by the arches over the entrances to the passages *A* and *B*. Now, as the dome is a hemisphere, any section of it through the center of its plan will be a semicircle, whose radius is the same as that of the circular plan, and we can consider the semicircle *b c d* as a revolved section through the dome on the diagonal rib *b d*; *b c u y* will then represent that rib as it would appear when cut out of its plank with its lower end *b* resting on the corner, and its upper end *c* standing over the center *o*, a distance of *o c* higher than the end *b*.

Four of these ribs will constitute the diagonals *a c* and *b d*, and the jack-ribs as *o g*, *o h*, *o i*, etc. will have the same curve exactly as far as they reach, but their upper ends will

be beveled and pointed to fit in around *o*, while the lower

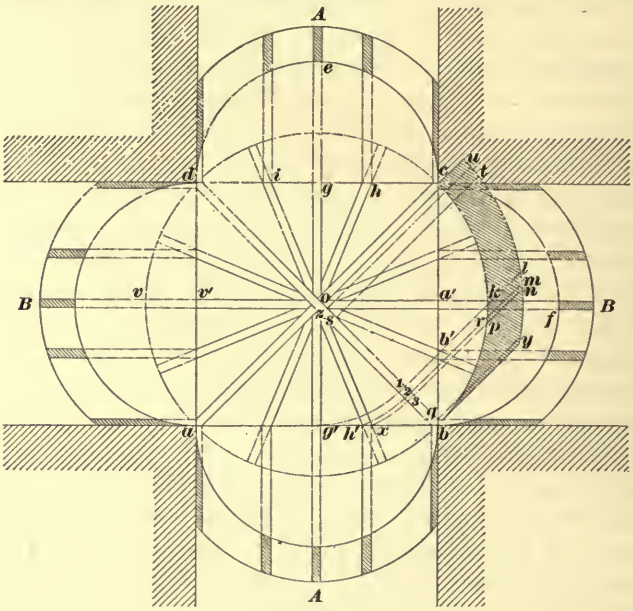


FIG. 88.

ends will require a plumb-cut and a cheek-cut to fit them against the arch pieces at *a b*, *a d*, *c b*, and *c d*.

214. To find the lengths and cuts for these jack-ribs, from the points *z* and *s*, where the sides of the ribs *o a'* and *o b'* intersect the side of the diagonal *o b*, draw *z u* and *s t* parallel to *o c*. The line *z u*, where it crosses the rib *b c u y*, will mark the shoulder from which to bevel the end of the rib *o a'*, and the line *s t* will mark the shoulder from which to bevel the rib *o b'*; the end piece *u c* will be cut off, as the rib *o b'* does not reach to the center *o*.

Now with *o* as a center, and with the radii *o g'*, *o h'*, and *o x*, describe the arcs *g' 1*, *h' 2*, and *x 3*, which will measure the lengths of each side of these jack-ribs on the diagonal rib *o b*; and the lines *1 l*, *2 m*, and *3 n* perpendicular to *o b* will cut the rib *b c u y* to the required lengths for the jack-rafters; *c u l k* will be the pattern for four of the jack-ribs

o g', *o a'*, *o g*, and *o v'*, the cheek-cuts being determined as explained above, and *c u n p* will be the pattern for the other jack-ribs, whose plumb-cut, where they join the arch ribs *c e d*, *c f b*, etc. will be the line *p n* on one side of the rib, and the line *r m* on the other side, while a line drawn on the top or bottom of the rib joining the ends of the plumb-cut lines will mark the cheek-cut or bevel.

215. In lathing the ribs of the passages, ordinary wood lath may be used, but the pendentives and dome must have metallic lath so that they may be smoothly finished in plaster.

216. Niches.—Vaulted, groined, and domed passages, such as those just described, seldom occur except in monumental work, and the side walls of such passages are often broken by niches for the reception of pieces of statuary, vases, etc. Fig. 89 shows the construction of such a niche. The plan (*a*) shows the base *a c b*, composed of $1\frac{1}{4}$-inch plank; halved into the front edge of this base are the two studs *a* and *b*, shown in the elevation (*b*) at *a'* and *b'*, extending from the base to the head piece *k*, to which they are nailed. The studs *n*, *o*, *p*, etc., extend from the base to the plate *l*, on which rests the curved ribs *n'*, *o'*, *p'*, giving the head of the niche a semi-domical form; the front is closed by two quarter-circle ribs *e f g*, let in and nailed to the studs *a'* and *b'*. Bridging, or stiffeners *s*, are inserted between the ribs, and the whole is then lathed with wire, or other metallic lath. The proportion of such a niche should be such that its height to *e* should be twice its width between *a'* and *b'*.

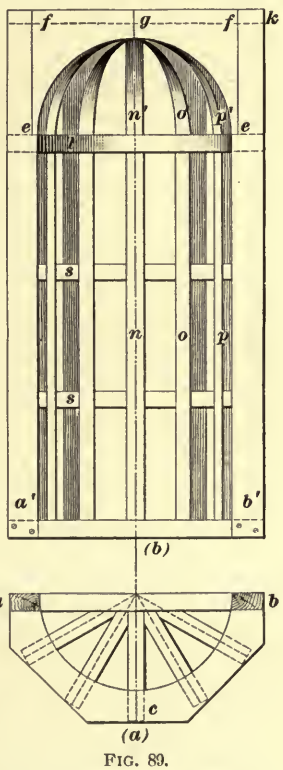


FIG. 89.

SLOW-BURNING CONSTRUCTION.

217. When a wooden building is constructed of good, sound, well seasoned material, and the workmanship on that material is first class in every respect, there is no reason why the house should not last 80 or 100 years, or even more, providing it does not burn down. In both braced-frame and balloon-frame buildings, the construction consists of a number of small pieces, such as studs, braces, floorbeams, etc., which burn rapidly and fiercely when a fire once gets started, and the spaces between the beams and studs form flues which give draft to the fire and spread it throughout the structure. If the building is not entirely destroyed the contents is usually ruined by smoke and water, and the beams and studs are burned and charred so that they are too weak to carry their loads, and have to be reinforced, or replaced. The immense quantity of water thrown into a building to extinguish the flames saturates all the material of which the building is composed, passes through the floors and partitions, runs down the staircases into the cellar, and soaks into the ground and foundation wall, often causing the house to settle in places and render a good job of repairing almost impossible.

In mills and factories where the floors carry heavy machinery, the fire eats the beams underneath, until the floor finally gives away and the machinery crashes through into the basement, causing the complete destruction of everything in its path.

In order to obviate many of these difficulties, **slow-burning construction** was introduced, and though at first used only in factories and mills, it is now frequently applied in every form of wooden building, including even residences and barns.

218. The fundamental principle of this form of construction lies in the omission or alteration of every detail of balloon or braced frame construction which would tend to make combustion rapid or easy. The individual members,

such as beams, columns, etc., are so proportioned that they retain strength enough to do the work required of them even after one-third of their bulk has been charred or burned. Instead of a large number of small pieces, as in balloon and braced frame construction, there is a small number of very large pieces in the slow-burning construction. Instead of $2'' \times 9''$ or $3'' \times 10''$ floor joists spaced from 12 to 24 inches on centers, we have $6'' \times 10''$ to $12'' \times 14''$ floor-beams spaced from 3 to 10 feet on centers. On top of these beams the rough floor is placed, but consists of from $3'' \times 6''$ to $3'' \times 9''$ planks grooved on both edges to receive $\frac{3}{4}'' \times 1\frac{1}{2}''$ hardwood tongues, or **splines,** as they are called. The boards may be blind-nailed to each beam through the under lip of the groove. Before the spline is inserted the joints should be driven close and tight. Over this flooring is spread a layer of heavy felt, then cross-furring with $\frac{7}{8}$-inch strips at 12-inch centers, the spaces between the strips being flushed with ordinary lime mortar. The finished floor is then laid with $1\frac{1}{4}$-inch matched material. The furring strips may with advantage be run diagonally, thus reducing the effect of vibration caused by the machinery. The lime preserves the wood from decay; being a non-conductor, it retards the passage of heat between the floors, and at the same time it tends to make the floor waterproof, as it absorbs the oil which drops from the machinery.

The roof is covered with 2-inch plank and is rendered waterproof with tin, copper, tar and gravel, or painted canvas, though when the pitch is steep, slate and shingles are both used. When slate is the covering material, care must be given to see that the roof-boarding is extra thick and close-laid, as in case of fire, when the roof becomes heated and water is thrown upon it, the slates will crack and fall off. The inside walls of mills and factories are not plastered or finished in any way more than to make the construction clean and neat where it is fully exposed to view.

219. The ultimate objects of this form of construction may be summed up as follows: To make a building strong

enough to stand any ordinary stress, even after its timbers are partly burned; to make the floor so tight and strong that when a fire starts in one story, the water poured in to quench it will not run through and ruin goods on the floor below; to avoid any corners, pockets, or flues where fire could get started without being immediately discovered; and, above all, to provide a building where every part is easily accessible and the fire can be attacked and extinguished at close quarters without flooding the entire structure.

220. The details of this construction can be best understood by referring to Fig. 90, which is a perspective view of the flooring and supports of a portion of a mill erected according to the rules of "slow-burning construction."

In this example wood alone is used, though iron, brick, stone, and other refractory material often enter into the construction of buildings of this class. The posts *a* in the first story are $10'' \times 10''$ Georgia, or long-leaf, pine, and those in the second story *a'* are $9'' \times 9''$ of the same material. The girders *b* are of $12'' \times 14''$ Georgia pine, with a span of 15 feet from center to center of posts. Between the top of the posts and the bottom of the girders is placed a **bolster** *c*, which is 6 in. $\times$ 12 in. in section and 2 feet 3 inches in length. On top of this bolster the next column is placed, and on its projection, on each side of the column, rest the ends of the girders *b*, which may be secured in place by means of lag-screws.

Longitudinally through the center of each post *a*, and also through the bolster *c*, is bored a $1\frac{1}{2}$-inch hole, and at *e* are shown $\frac{1}{2}$-inch holes bored transversely through the ends of the column to give ventilation to the interior and prevent dry rot. Sometimes the under side of the bolster is countersunk, or rabbeted, about an inch deep in order to fit over the top of the post below, but a simpler method of securing it in place is by means of a piece of iron pipe inserted into the hole *d* as a dowel. **Drift pins,** or long spikes, may also be used for this purpose. After the columns and bolsters are set and the girders are in place upon them, the $4'' \times 6''$ cleats

f are bolted to the lower edge of the girders through the holes *g*, which have been previously bored to receive them.

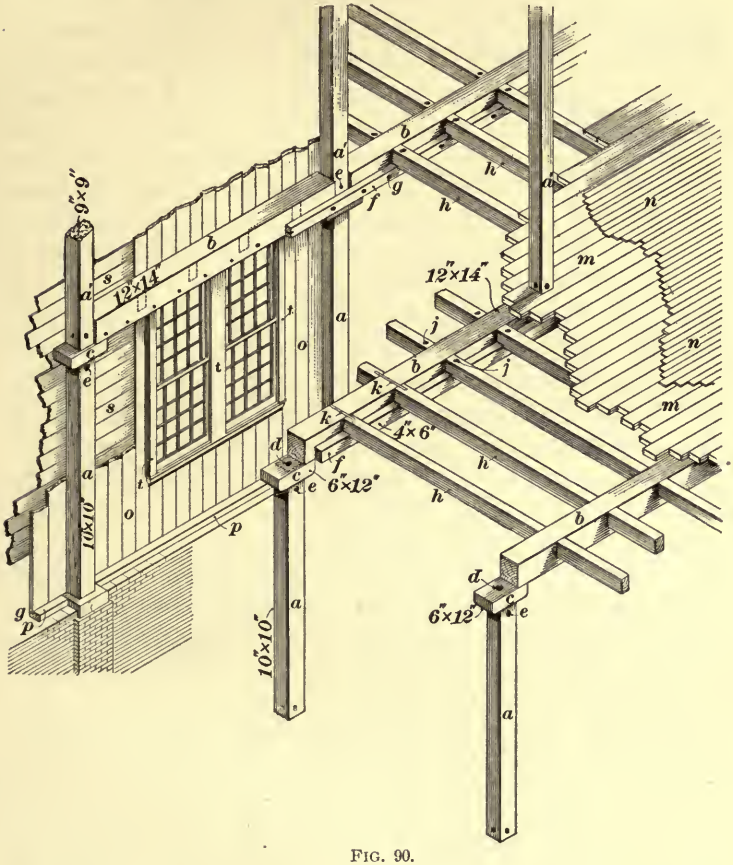


FIG. 90.

These cleats serve the double purpose of tying the girder system together longitudinally, and of forming a seat for the ends of the floorbeams *h*.

221. The floorbeams *h* are 6″×9″ Georgia pine, their lower sides being notched about 1 inch to bring their upper edges in line with the top of the girders *b* and are spaced 3 feet on centers. About 3 inches from each end of each

floorbeam a $\frac{3}{8}$-inch hole is bored 2 inches deep, as shown at *j*, into which iron "dogs," shown at *k*, are driven; when the beams are in place, a dog made of a $\frac{3}{8}$-inch round iron bar, 22 inches long, with 2 inches of each end bent at right angles, is driven tightly into the holes in the top of the floorbeams. This is shown more clearly in Fig. 91, where *a*, *a* are the $\frac{3}{8}$-inch holes bored in the top of the floorbeams *c*. The purpose of the iron dog is to secure the ends of the floorbeams *h*, prevent them from slipping off the cleat *f*, and thereby form a continuous tie throughout the length of the building.

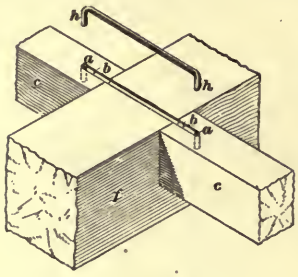


FIG. 91.

The floorbeams being in place and anchored, the under floor *m* is laid. This consists of 3-inch planks not more than 6 inches wide and planed on both sides, giving a finish to the ceiling in the story below. Two of these $3'' \times 6''$ planks are shown at *a*, *a*, Fig. 92, *b*, *b* being the grooves cut in both edges of each plank, and *c*, *c* the tongues of $1\frac{1}{2}'' \times \frac{3}{4}''$ Georgia pine inserted in each groove as the board is laid. This renders the floor rigid, and the surfaces of the planks are kept flush.

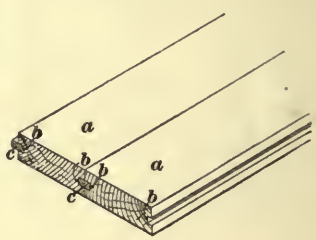


FIG. 92.

The finished floor *n* is then laid with $1'' \times 4''$ or $1\frac{1}{8}'' \times 4''$ maple, or hard pine, tongued and grooved and surfaced. The furring strips and felt lining above referred to are omitted in the cut to avoid confusion of lines.

Instead of the mortar filling between the rough and finished floors, several layers of waterproof sheathing paper is sometimes substituted, and though it renders the floor quite as water-tight, it is not so impervious to heat as the mortar, and, consequently, will not retard the progress of fire as well.

222. The outside walls of the building are built in the same manner as the interior; that is, posts support the outside ends of girders, and girders support the outside ends of floorbeams. The rectangular space enclosed by two posts and two girders, or floorbeams, is then closed in with 2-inch tongued and grooved plank laid vertically, as shown at *o*, in Fig. 90. The sill *p* is laid on the brick foundation wall, and may be rabbeted at *g* to receive the ends of the two-inch plank *o*. The entire exterior of the building is then sheathed with ordinary $1'' \times 8''$ sheathing boards *s*, over which matched and beaded planks may be laid vertically to form the exterior finish, or patent or beveled siding may be laid in the same manner as in a balloon frame. When the latter course is pursued, the sheathing boards *s* are usually laid diagonally, in order to prevent irregular courses of the clapboards, due to the shrinkage of the sheathing.

The window frames, being thicker than the boarding of the walls, are allowed to project inside, and are finished with a casing, as shown at *t*. The enclosing walls, therefore, act only as a protecting screen to the building, as the floor system is carried entirely by the posts and girders, and although these walls are but 4 inches in thickness, they are warmer and better in every way than the 7-inch stud and plaster partitions of the balloon frame.

223. **Interior partitions** are constructed of 2-inch tongued-and-grooved plank laid vertically from floor to ceiling, each plank being toe-nailed to the floor and ceiling cleats and driven well up against its neighbor. Where a neat finish is required on the partitions, as would be the case in enclosing a private office, the 2-inch plank may be lined with $\frac{7}{8}'' \times 3''$ matched boards of oak, or hard pine, laid horizontally or diagonally, or it may be plastered as explained further on in the application of this form of construction to residence work.

224. **Roofing.**—The roof of such a building as that shown in Fig. 90 should be as nearly flat as is consistent with a proper watershed, and built of 2-inch plank laid on roof

beams corresponding in position and spacing with floor-beams below. The roof beams need not be the same size and strength as the floorbeams, but should, under any circumstances, be of such proportions of breadth to depth as will insure their slow combustion should a fire get any headway beneath them.

225. This description of the essential features of mill construction applies to such buildings as are built entirely of wood, no important member being of iron or steel, and nothing save the foundation being of brick or stone.

Modifications of the details are, therefore, necessary, where the walls are of brick or stone; where the columns are of steel or cast iron; or, where the girders are composed of rolled-iron or steel beams.

226. Wooden beams, or girders, resting one or both ends on a brick wall, should have an air space all around the top sides and end of the beam to give ventilation and prevent dry rot. This may be done by keeping the brickwork $\frac{1}{2}$ inch away from the sides of the beam when it is built in the wall, but is much more satisfactorily accomplished by use of the Goetz-Mitchell anchor, shown in Fig. 93. This consists of an iron box, cast to fit the end of the beam, and possessing two projecting flanges *a*, which are enclosed in the brickwork of the wall, rendering the anchor a fixture. The box is cast about $1\frac{1}{2}$ inches wider inside than the wooden beam is broad, and about $\frac{1}{2}$ inch higher than the beam is deep.

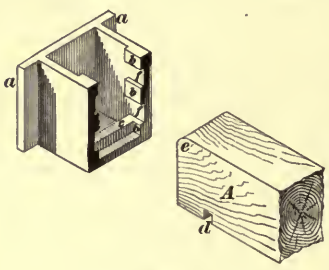


FIG. 93.

Along the front edge of the casting are square cheeks *b* projecting about $\frac{3}{4}$ inch from the general surface of the interior. When the end of the wooden beam *A* is inserted in this anchor it is notched on its under side to fit over a raised fillet *c*, and the spaces *f* between the cheeks *b* give ventilation all around the beam inside the box-like casting. The

fillet *c* is generally 1 in. × 1 in., and the notch *d* in the beam, fitting tightly over it, prevents the timber from pulling out of the wall. The top of the beam is rounded off at *e*, so that should the beam become burned through at its center, it can fall down and out of the wall without disturbing any of the brickwork and thereby endangering the stability of the wall. The advantage of this is illustrated in Fig. 94, where (*a*)

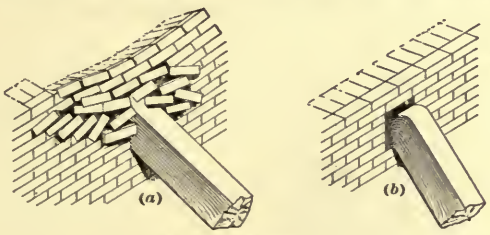


FIG. 94.

shows the destructive effect of a beam falling from a wall to which it has been anchored with the ordinary strap anchor, shown at *k* in Fig. 32, while at (*b*) the beam is seated in the cast-iron anchor above described, from which it can fall without damaging the wall in any way, and leaves the anchor intact to receive a new beam when repairs are made.

227. When this Goetz-Mitchell anchor is used in the masonry of a building, it is customary to replace the hardwood bolster shown at *c*, in Fig. 90, with the cast-iron post cap shown in Fig. 95. This cap is cast with a socket 4 inches or 5 inches deep on its under side to fit the top of the wood posts, while flanges, shown at *d*, are left on its upper side to embrace the ends of the girders resting upon it. Holes are cored through the metal at *a* to ventilate the top of the post and ends of the girders, and thereby lessen the danger of dry rot, while a large hole *b* in the seat of the cap permits the insertion of a dowel in the top of the column

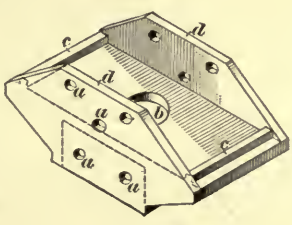


FIG. 95.

below, to which a superimposed post may be fitted. When used with this cap the girders are notched over the fillet *c* in the same manner as shown in Fig. 93, and a space of about $\frac{1}{2}$ inch is left between the ends of the girders and the sides of the post which is set between the upper flanges.

These anchors and caps are protected by United States patents, but may be cast in any foundry on the payment of one-eighth of a cent per pound to the Goetz-Mitchell Company, of New Albany, Indiana.

228. Cast-iron columns are frequently used in this class of construction on account of the ease of securing rigid connections between the columns and beams, and also between the columns themselves in different tiers. Brackets are left on such columns to which the carpenter is to seat and anchor the ends of his beams and girders; when these brackets are cast with a fillet, as shown at *d*, Fig. 96, the carpenter simply notches the under side of his beam, as for the caps and anchors above described. If a rolled-iron or steel **I** beam is used instead of a heavy wood girder, the carpenter will be called upon to sheath the beam in wood to protect it, and unless iron brackets are provided to seat the floorbeams on, he will also be required to provide a wooden ledge, as shown at *e*, Fig. 96, on which the beams are set and secured.

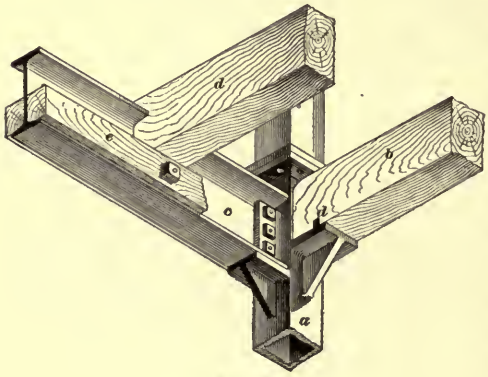


FIG. 96.

229. The methods of sheathing iron girders with wood and of securing floorbeams to them are numerous, and depend entirely on the purpose of the building and the economy of its construction. Under most circumstances, an exposed iron beam, such as is shown at *c*, will not stand the

heat of a fierce fire as long as a wooden girder of equal strength, such as is shown at *b*, in Fig. 90. The iron beam absorbs the heat and soon becomes so hot as to bend in the middle, thereby throwing walls and columns out of plumb, and finally causing a collapse of that entire part of the building in which it is located.

A wood girder does *not* absorb the heat, and when exposed to flames takes fire very slowly, commencing with the lower corners, or edges, and gradually burning up towards the center until it breaks through and precipitates its superimposed load to the floor, or cellar beneath.

If its ends are supported on a cap, such as shown in Fig. 95, or upon a bracket, as at *d*, in Fig. 96, it will probably release itself as it falls, and in no way endanger the floor above, as the burning material has been carried down with the girder and is farther away from the next tier above than before the floor fell. When, therefore, iron or steel beams are used in a building with wooden floorbeams they should be protected by wood; and the best method of accomplishing this protection is shown in Fig. 97, where *a* is a 15-inch **I** beam supporting, not only the floorbeams *b*, but also the partition *c*. Each side of the beam is filled and enclosed by two pieces of timber *g* and *g'*, which are worked to fit their positions from 4″×8″ stock and are held in place by $\frac{3}{4}$-inch to $\frac{7}{8}$-inch bolts *i* and *j*, spaced throughout the length of the beam *a* at about half the interval of the floorbeams *b*. The upper pieces of timber *g* are notched out where the floorbeams

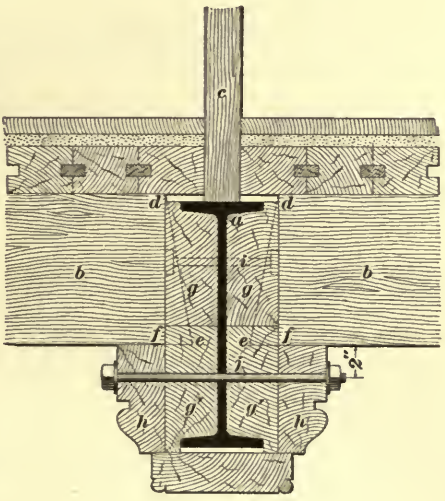


FIG. 97.

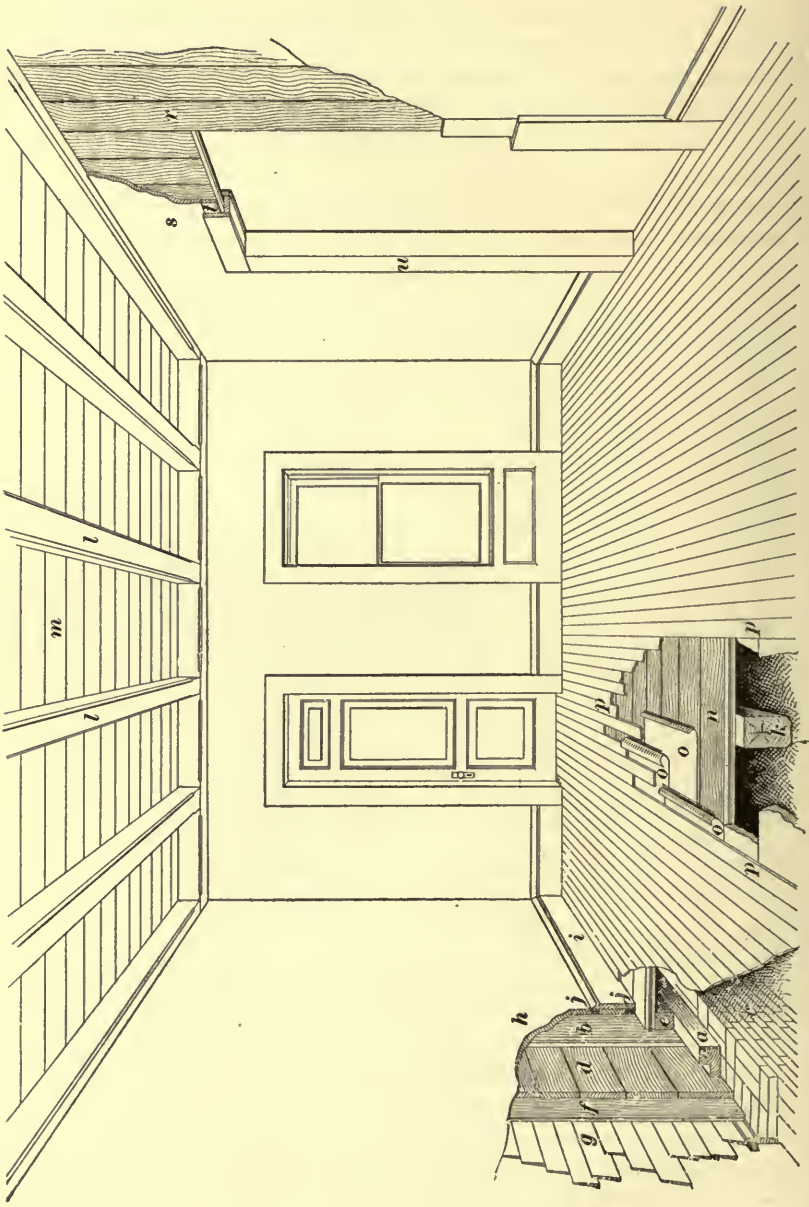


FIG. 98.

rest, as shown by the dotted line *d e f*. The end of the floor-beam is cut to fit this notch and seats itself on the lower timber *g'*, at *e f*. The bolt *j* passes not only through the two timbers *g'*, but also through the wooden ledges *h*, which are provided to give additional support to the floorbeams *b*.

Another piece of timber worked from 3″×8″ stock, is secured to the bottom of the girder, thereby enclosing the entire iron beam.

230. Where a partition is to be supported by such a girder, the 2-inch or 3-inch plank forming the body of the partition stands directly on the iron beam, as shown at *c*, Fig. 97, and the 3-inch splined plank of the under floor is laid up to it on each side.

The mortar filling is then spread on the rough floor, and if the side wall, or partition, is to be plastered, the mortar is then carried up the side wall, on wire lath, before the finished floor is laid. The finished flooring is then laid on the nailing strips between the mortar filling and securely nailed through to the 3-inch plank. If a base is to be carried around the room, grounds are set for it, against which the plaster stops, as in ordinary balloon or braced frame.

231. **Private Residences.**—It is only very recently that slow-burning construction has been applied to the building of frame dwellings, but it has been found to lend itself so readily to this purpose that the number of "mill-built" houses is increasing every day. Over and above the advantages of decreased fire risk, this system of construction gives the householder a residence warmer in winter and cooler in summer than can be attained by the ordinary balloon or braced frame, while it secures to him walls and floors through which it is absolutely impossible for mice and other vermin to run and breed; and it provides a house the endurance and lasting qualities of which are beyond anything to be secured in any other way, where wood is the material used.

232. Fig. 98 shows the interior of a room in a house built upon the system of slow-burning construction, portions of the floor and partitions being removed to show the

relation of the parts. At *a* is shown the sill 6 in. × 10 in. laid in lime mortar on the foundation wall *c*, while its outside edge has a rabbet cut in it 2 inches deep, to receive the ends of the 2-inch plank *b*, which take the place of studding in other framing. The sheathing *d* is ordinary 1″ × 9″ plank laid horizontally and thoroughly spiked to the 2-inch boards, while another layer of 1-inch sheathing is applied vertically outside of this, as shown at *f*. The object of this is to provide a surface to nail the siding *g* to, which will not throw the clapboards out of even alinement by its unequal shrinkage. If the siding were nailed directly to the sheathing *d* there would be danger of the clapboards separating in pairs as the boards *d* shrank in drying out. These three thicknesses *b*, *d*, and *f* also make the side of the house much stiffer and stronger than would the two layers *b* and *d*.

Sometimes, for economy of labor, the boards *b* are made 3 inches thick, and the boards *d* are laid over them diagonally; the siding is then applied to the diagonal boards.

The inside of the plank *b* is covered with stiffened wire lath and plastered directly against the wood; the stiffening ribs forming sufficient space for the clinch of the plaster. Grounds *j* are carried around the room before the plastering is done, and the base *i* is secured in place before the finished floor is laid.

The floorbeams, one of which is shown in section at *k*, are 6 in. × 9 in., spaced about 3 feet on centers. They should be planed and finished with sandpaper, the corners neatly chamfered, the surface receiving a coat of shellac varnish before they are set in place (provided that they are thoroughly seasoned), as they will form an open-timber ceiling in the room below, as shown at *l*. For the same reason the 2-inch plank *n* which forms the under flooring should be from selected stock, free from sap, shakes, or loose knots, and its under side should be planed and sandpapered before it is laid, as it forms the ceiling in the floor below, as shown at *m*. Over the underflooring *n* is laid one or two thicknesses of heavy felt *o* or a 1-inch layer of mortar, as previously described. The finished floor *p* is then laid in narrow strips, blind-nailed to the nailing strips and closely driven.

Inside partitions are formed of 2-inch plank set vertically, as shown at *r*, and plastered on both sides on wire lath, as shown at *s*. Around all door and window openings is carried a ground *t* against which the plaster stops, and to which the trim *u* is nailed.

233. The whole structure is thus rendered solid, substantial, and unyielding to any ordinary strain, while the absence of any small timbers reduces the fire risk to a minimum.

The first cost of this style of construction is greater than balloon frame or braced frame, but the saving in insurance rates and the reduction in the quantity of coal required to heat the house in winter offsets the interest on the extra money invested.

It is imperative that the timbers be thoroughly seasoned before paint, varnish, or other impervious coatings be applied, otherwise the natural sap, being prevented from evaporating, will ferment and cause *dry rot*. In mill-built structures, it is, therefore, customary to allow the heavy timbers to dry out for two or three years before they are painted.

To insure first-class work in any system of wood construction, it is essential that the wood be thoroughly seasoned, be free from sap, shakes, loose knots, and the other imperfections described. When in position in the building, it must be kept not only dry, but due provision must be made that no portions are so tightly sealed that pure air cannot come in contact with them. Timber thus excluded from pure air, whether in a damp or dry position, will soon rot; so that where impervious layers of paper, felt, etc. are applied, they should be in contact with only one of the surfaces.

234. The following table gives the sizes of timber used in the systems of wood construction of buildings heretofore described. These sizes are not absolute, and vary according to circumstances, but may be taken as a good average where any doubt may exist:

	Balloon-Frame Building Not Over 1,500 Sq. Ft. Area.	Balloon-Frame Building Over 1,500 Sq. Ft. Area.	Braced-Frame Building Not Over 1,500 Sq. Ft. Area.	Braced-Frame Building Over 1,500 Sq. Ft. Area.	Slow-Burning Construction.
Corner posts	$2'' \times 4''$ and $4'' \times 6''$	$2'' \times 6''$ and $6'' \times 8''$	$2'' \times 6''$ and $4'' \times 8''$	$2'' \times 6''$ and $6'' \times 8''$	$10'' \times 10''$
Sill	$4'' \times 6''$	$4'' \times 8''$	$4'' \times 10''$	$4'' \times 10''$	$6'' \times 10''$
Plate	$3'' \times 8''$	$4'' \times 10''$	$6'' \times 8''$	$6'' \times 10''$	$6'' \times 10''$
Interties			$4'' \times 8''$	$6'' \times 8''$	$8'' \times 10''$
Ledger boards	$1'' \times 4''$	$1\frac{1}{2}'' \times 4''$			
Double studs	$3'' \times 4''$	$4'' \times 6''$	$4'' \times 6''$	$6'' \times 6''$	$2''$ or $3''$ plank
Single studs	$2'' \times 4''$	$2'' \times 6''$	$2'' \times 4''$	$4'' \times 6''$	
Braces	$2'' \times 4''$	$2'' \times 6''$	$4'' \times 6''$	$6'' \times 6''$	$6'' \times 8''$
Sheathing	$1'' \times 9''$	$1'' \times 9''$	$1'' \times 9''$	$1'' \times 9''$	$1\frac{1}{2}''$ plank, 2 thicknesses
Rough floor	$1'' \times 6''$	$1'' \times 6''$	$1'' \times 6''$	$1'' \times 6''$	$3''$ to $4\frac{1}{2}''$ plank
Finished floor	$\frac{7}{8}'' \times 4''$	$\frac{7}{8}'' \times 4''$	$\frac{7}{8}'' \times 4''$	$\frac{7}{8}'' \times 4''$	$\frac{7}{8}''$ to $1\frac{1}{2}''$ plank
Floorbeams	$2'' \times 8''$ to $3'' \times 10''$	$3'' \times 9''$ to $3'' \times 12''$	$3'' \times 8''$ to $3'' \times 12''$	$3'' \times 9''$ to $3'' \times 12''$	$4'' \times 6''$ to $10'' \times 12''$

JOINERY.

PROVINCE OF JOINERY.

1. Joinery, as distinguished from **carpentry,** relates to that branch of the woodworking trades which deals with those internal and external fittings of a house that are put in place after the rough framework and flooring are finished, such as the *floors*, *skirtings*, *casings*, *wainscotings*, *doors*, *windows*, *paneled partitions*, *stairways*, etc.

In joiners' work, close-fitting joints, accurate workmanship, and smooth finished surfaces are the chief points in view, as contrasted with the work of the carpenter, whose main object is to provide a frame or skeleton which shall be strong enough to resist any stress to which the building may be subjected, and arranged to comply with the requirements of the finished joinery.

Hence, while the latter deals principally with heavy timbers in the rough, the former uses smaller pieces of finer and more carefully seasoned woods, and joins and fits them with the utmost accuracy. The joiner, therefore, must work with much more care and to a higher degree of finish than the carpenter. All the surfaces he leaves exposed must be smooth and clean, ready for the painter, varnisher, or polisher.

His time is spent between the duties of the workshop and

the building. In the workshop, he prepares the framed and paneled work, door frames and casings, window frames and sash, all classes of molded work, the various parts required for stairways, general trim and interior fittings. In the building, he attaches the finished woodwork to the framed base, consisting of false jambs, furring strips, and grounds, all of which the joiner should verify as to correct leveling, plumbing, and alinement before he applies the materials. True, these should have been placed correctly by the carpenter, but the careful joiner will always make an examination of existing conditions, so that he may better meet them intelligently.

JOINTS.

2. To insure durable and flush connections between the parts joined together, due consideration must be given to the form and character of the joints, so that the strains to which they are subjected may be either resisted or compensated. The strains may be caused either by the behavior of the material itself or by extraneous force in the working portions, as doors, shutters, and window sash.

In *Carpentry*, a number of joints commonly used in house building are described in detail; and though many of these joints are identically the same in principle as those used in joinery, there is a vast difference in the degree of accuracy required in the workmanship. In joiners' work, the joints may be divided into two classes, namely, *loose* joints and *glued* joints; the former consists of two or more pieces maintained in place by the shape of the parts of union, such as the dovetail joint, Figs. 8, 9, and 10; in the latter, the pieces are secured by means of glue, as in the miter joint, Fig. 2, the halved corner, Fig. 3, etc.

3. **Loose joints** are seldom used in joinery, except in heavy machine frames, and in pieces of cabinetwork which are made in sections for convenience of handling, or in the exterior finish of a building where exposure to the weather

would render the glued joint unreliable; and, in any case, the loose joint is usually rendered additionally secure by means of screws, nails, or wooden pins.

4. Glued joints require some mechanical contrivance to maintain them in position while the glue is setting, which usually requires from 12 to 48 hours, according to the quality of the glue, the condition of the atmosphere, and the temperature of the room.

5. Considerable experience is required in order to use glue successfully. The wood must be well seasoned and thoroughly dry, and the joint must be well fitted. In gluing hardwoods, the surfaces to be glued should be roughened with a toothed comb, to make the glue hold better; the room must be at a proper temperature, and the material must be heated, so that the glue will flow quite freely. The glue must be spread evenly on the parts, which are then placed together as soon as possible, and maintained in place by means of hand screws, bench clamps, or wedged frames. All superfluous glue is then wiped off and the work left until the joint is thoroughly dry.

The most frequent causes of bad gluing are the use of an inferior quality of glue and the unequal spreading of it. A good practical way to test any brand of glue is to glue together a piece of pine and a piece of ash, clamp them up with a hand screw, and when they are dry insert a chisel in the joint and try to pry them apart. If the joint separates where it is glued, the adhesion is inferior, and should not be used for first-class work. The wood should split or give way rather than the material securing the joint.

6. The simplest joint made use of in joinery is the **butt joint,** shown in Fig. 1. Here the two pieces joined are simply butted together, in a similar manner to the butt joint in carpentry, but the adjacent surfaces are much more accurately fitted, and are held in place by means of screws or dowels—the former when the pieces joined are broad and

thin, as in Fig. 1 (*a*), and the latter when the timbers are heavy and thick, or when they are joined together on the thinner edges, as at Fig. 1 (*b*).

This joint is insecure in itself, and usually requires glue to make it in any degree reliable; or it may be kept in place by the woodwork behind, against which it is erected, as

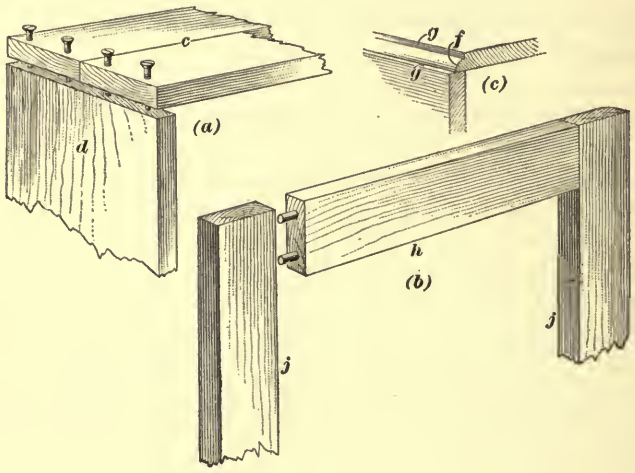


FIG. 1.

would be the case in an exterior casing for a window where the form shown at (*b*), Fig. 1, would be used, except that the top *h* would rest upon the sides *j*.

The plain butt joint, shown at Fig. 1 (*a*), is seldom used in first-class joiners' work, as the opening caused by shrinkage is very apparent. The absence of a device to keep the entire surface flush allows the fibers to curl, and the effect of shrinkage and warping would be to cause the pieces *c* in Fig. 1 (*a*) to project slightly over the side of *d* and render the juncture too apparent. This may be obviated to a certain extent when the grain runs parallel to the joint, by forming the joint as at (*c*); a quarter-round *f* is worked on one of the pieces to be joined, thus forming fillets, as shown at *g*. The joint, Fig. 1 (*a*), may also be doweled, as shown at Fig. 1 (*b*).

7. The **miter** joint, shown in Fig. 2, is generally used when the boards are of the same thickness, where no great strength is necessary, and where the conditions require that the angle shall show no end grain of the wood, either inside or outside of the joint. It is usually nailed or screwed together as shown, but depends upon glue to make it secure, or is strengthened by a slipfeather or spline, as shown dotted at *a*. It is also sometimes secured by gluing in a key of thin wood, which is inserted in a saw kerf cut diagonally, as at *b*, or at right angles to the end, as at *c*. A keyed miter is most generally used for a joint seen only from the interior, as the keys disfigure the exterior appearance. This joint is also made with the broad portion of the wood on the face, as in the case of architraves and casings.

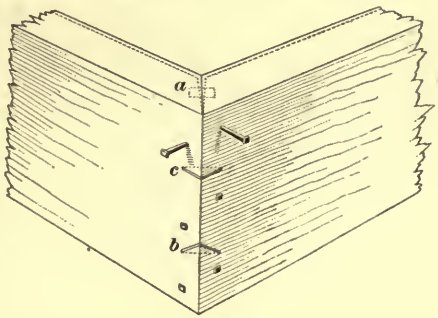


FIG. 2.

In mitered joints, the shrinkage of the wood does not change the appearance of the exterior of the joint, but causes the interior to open slightly, as indicated by the dotted lines. To obviate warping, however, a tongue is very essential.

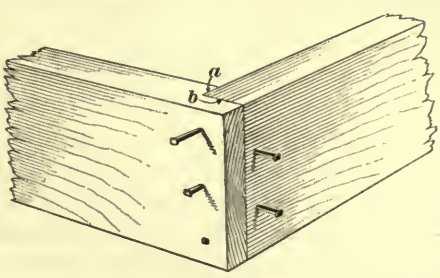


FIG. 3.

8. The **shouldered corner,** shown in Fig. 3, is a joint used where the inside angle will alone be visible, and is an improvement on the butt joint shown in Fig. 1 (*a*), inasmuch as it provides two nailing surfaces, one at *a* and one at *b*.

9. The **shouldered-and-mitered** joint, shown in Fig. 4, is a combination of the forms shown in Figs. 2 and 3. It

presents the advantages of showing no end grain as does Fig. 3, and possesses the additional strength secured in the method of joining the pieces of Fig. 3. Its use, however, is limited to light work, where no great strength is required, and is principally serviceable where a miter joint is required between pieces of unequal thickness, as in Fig. 4.

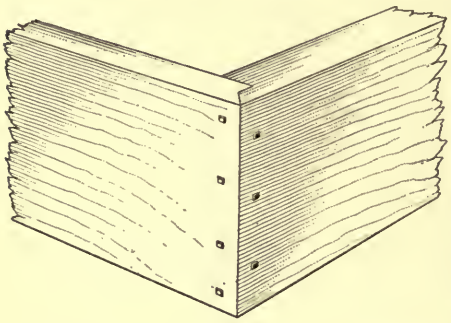


FIG. 4.

10. The **tongued-and-grooved** joint, Fig. 5, the **dado** joint, Fig. 6, and the **housed** joint, Fig. 7, are all modifications of the same form, where the end of one piece

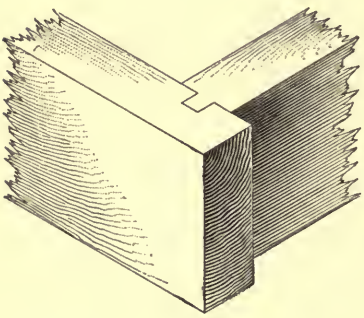


FIG. 5.

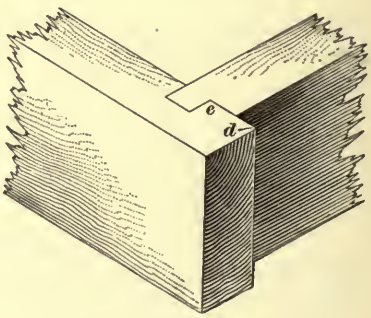


FIG. 6.

is let into the side of another piece about one-third of its entire thickness. These joints are very frequently used in joinery. They are secured by means of glue, nails, or screws, or may be left loose to allow the members to come and go in shrinking and swelling.

In joining the back and sides of a drawer, the forms shown in Figs. 6 and 7 are very frequently used, as the projection of the sides of the drawer, as from *e* to *d*, renders the end less likely to be pulled off by the jar of the contents when

the drawer is suddenly opened; and any unequal shrinkage of the two pieces will not tend to split the material, if the joint is not secured by too many nails.

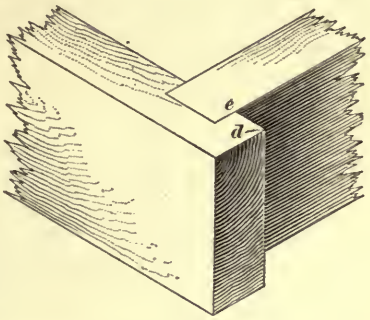


FIG. 7.

11. The **dovetail** joint is one of the most important in joinery. It furnishes a rigid method of securing pieces together where the fibers of the material are approximately at right angles with the joint.

Upon analyzing the conditions of strength existing in a dovetail joint, it is evident that the strength of the entire joint depends upon the combined value of the dovetails, the same as a nailed joint depends upon the combined resistance of the nails, or as a nut on a bolt depends upon the aggregate strength of the threads for its holding power.

The extent to which this is true may be realized by considering wherein lies the strength of each dovetail.

In Fig. 8, the projections *e* upon the piece *b* are liable to fail by the shearing of the flare or dovetail upon each side of the projection, the strength in this case depending upon the capabilities of the wood to resist shear across the grain; while the projections upon the piece *d* depend for their strength upon the resistance of the flares or dovetails to the shear of the wood parallel to the grain.

The projections upon the pieces *d* and *b* are also liable to fail by shearing through, or by breaking off where they join the main pieces of wood; consequently, the distance *h h* and the corresponding distance on the projections on the piece *b* should never be so slight as to be liable to break before the shearing strength of the wood across, or parallel with, the grain is realized.

There is still another factor entering into the strength of a dovetail joint, and that is the adhesive strength of the glue which binds the fibers of the projections upon the pieces

united, giving rigidity to the joint and preventing the piece *d* from pulling away from *b* in a direction parallel to the grain of the latter.

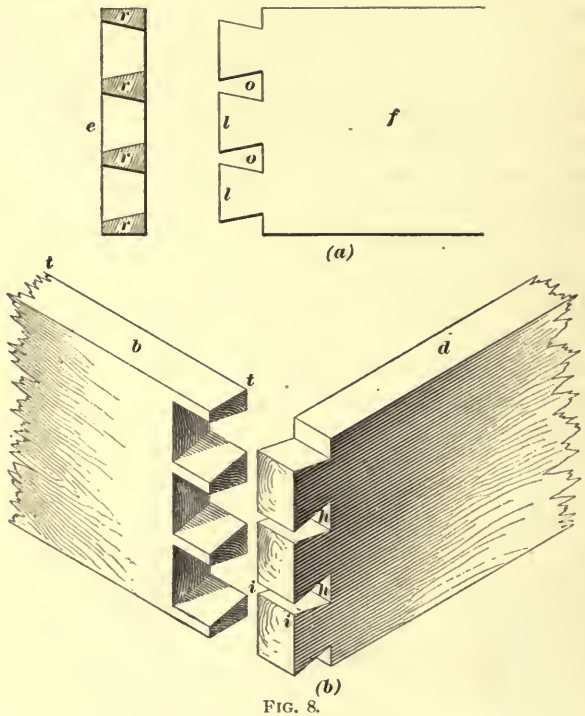


FIG. 8.

12. Dovetail joints are of three kinds. One form, shown in Fig. 8, and known as the **lap dovetail,** has its dovetails on *d*, and its dovetail pins projecting from the body of the piece *b* a distance equal to the thickness of the piece *d*. The ends of the pins and dovetails show on opposite sides of the corner when the pieces are joined.

13. Another form, known as the **half-lap dovetail,** shown in Fig. 9, is a joint in which the pins *c*, though cut down from the end of the board *e* a distance equal to the thickness of the board *h*, are not cut entirely through the board *e*, but have, as at *f*, *g*, a lap which, when the joint is closed, covers the end of the dovetails on *h*, and prevents

the character of the joint from appearing on *e* at all, though the end grain of the pins *c* will show through the board *h*. This joint is well adapted for the fronts of drawers, as shown at (*a*), as the piece *e*, which shows no dovetails, forms the

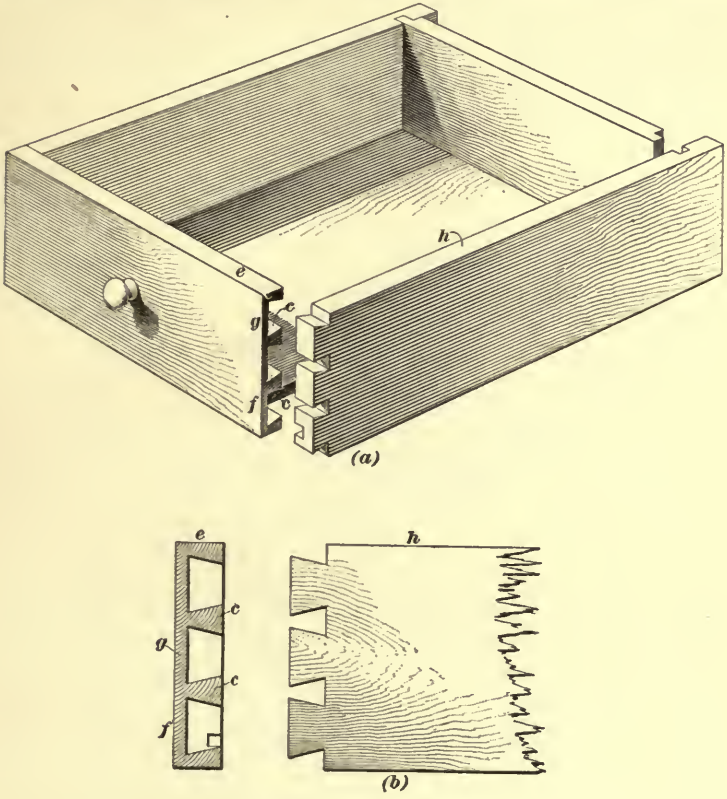


FIG. 9.

front of the drawer, and the ends of the dovetail pins on the side piece *h* are hidden when the drawer is closed. The side elevation of the joint, and the relative size of the dovetails and dovetail pins, are shown at (*b*). The reference letters refer to the same details in both (*a*) and (*b*).

14. The third form is known as the **blind** or **secret dovetail,** and is shown in Fig. 10. In this joint about

three-fourths of the thickness of the board is dovetailed, the remaining portion being united in a miter joint. Both the dovetails and the dovetail pins are here cut only partially through the board, and the upper pin a' of the piece c is cut off on the miter line of the angle, while the upper half mortise b' is cut only to the miter line of the piece d, thereby concealing entirely the details of the true character of the joint, when the pieces are united.

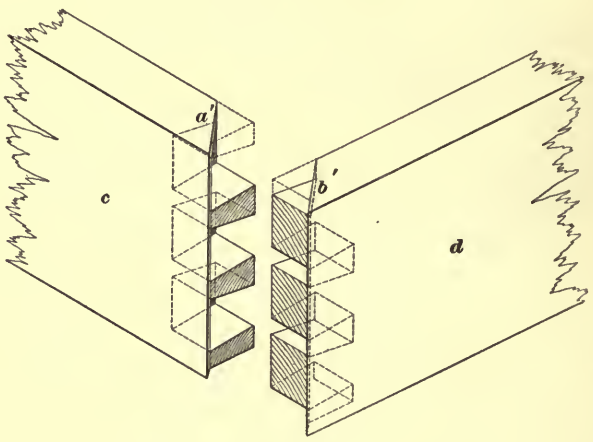


FIG. 10.

This joint is seldom used in joinery, except for the front corners of highly finished drawers and boxes, where, for the sake of appearance, it is better for the dovetails not to show. The blind dovetail is not as strong as either of the other forms, partly because it utilizes only a portion of the available thickness of the wood, and partly on account of their concealment, it is impossible to see whether the pins and mortises fit each other accurately.

In preparing the dovetail joint, the pins r, Fig. 8 (a), are marked and cut first; the piece e is then laid across the end f, and the mortises o are carefully scribed with a knife-point on the side of the end of f. The pins must be sawed square from the end, or parallel to the edge $t\ t$ in Fig. 8 (b), and the mortises must be cut square across the end of d as at $i\ i$, the greatest neatness and accuracy being required to insure good work.

15. In all joiners' work, face and edge marks are made so as to distinguish the face and edge from which all measurements must be taken and all squaring done. At the same time they serve to assist the joiner in determining the edges that are to be in contact, and prevent mistakes due to putting the pieces together in other than their proper relations.

16. The **doweled** joint, shown in Fig. 11, consists of a plain butt joint between the two pieces *e* and *f*, either

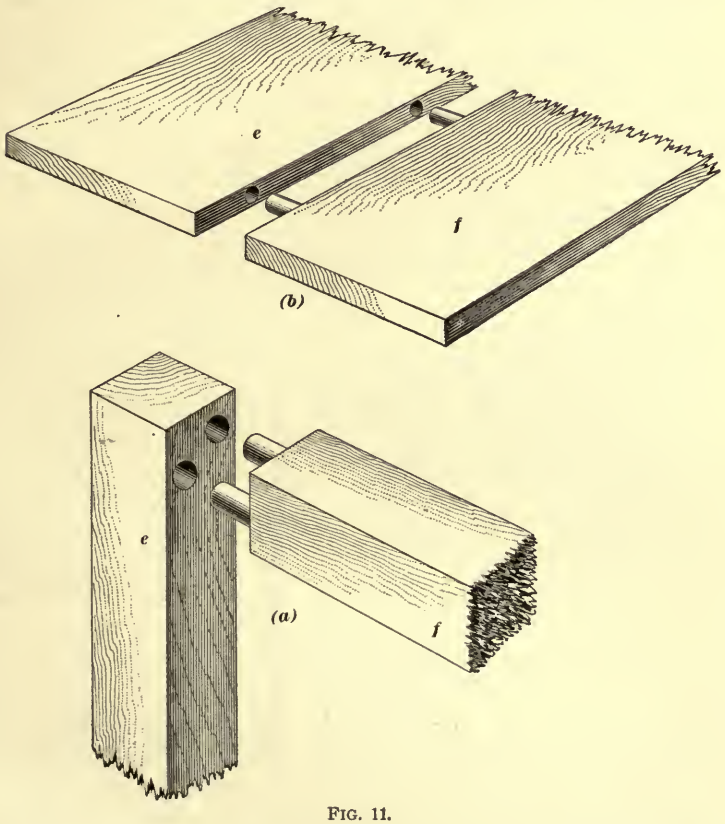


FIG. 11.

between one end and a side, as at (*a*), or between the two meeting edges, as at (*b*). Holes are bored and dowels are glued and inserted as shown. The object of the dowels is

to keep the faces flush, and render the joint stiffer if subjected to a transverse strain. The holes should be somewhat deeper than the length of the dowels, to allow for shrinkage of the material and at the same time insure a close joint. The form shown at (*a*) is a substitute for a mortise-and-tenon joint, but is not to be recommended.

17. The **mortise-and-tenon** joint as used in joinery is precisely the same in principle as the same joint in carpentry but the fitting is much more accurate. This joint, in varied forms, is used to secure the rails and stiles of doors and windows, to unite the members of heavy machine frames, and to connect the various parts of tables, chairs, and other pieces of furniture.

18. Keys and Keying.—When broad, plain surfaces, such as dados, window backs, table tops, etc., are required, the boards forming them are generally tongued-and-grooved together, or they are doweled and united with glue; but, to secure the surface against warping or twisting, pieces of wood called *keys* are let into a dovetailed groove in the back, as shown at *a*, Fig. 12. These keys are either planed off flush with the surface into which they are sunk, or, when extra strength is required, they may stand up from the back, as shown at *b*. They should not be glued in position, but are sometimes secured with a single screw or nail at one end, as shown at *c*, so that when the material shrinks it will slide upon the key, and the joint along the keyway or groove will still remain tight.

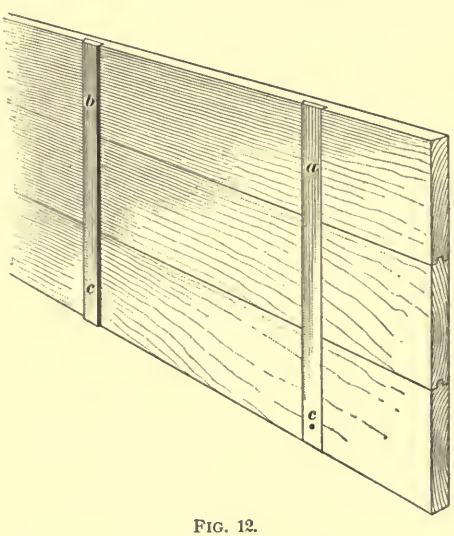


FIG. 12.

19. Clamping.—Boards are sometimes maintained against warping by means of clamping, as shown in Fig. 13. The boards *a* and *b* are doweled or tongued-and-grooved together on their interior edges to form a close joint, as at *c d*, and the clamps *h*, *j* are glued over tongues worked on the ends of *a* and *b*, as shown at *e*.

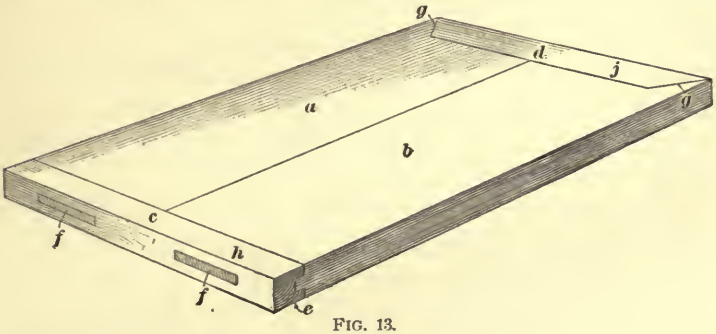


FIG. 13.

In first-class work, tenons *f* are also worked on *a* and *b*, and by insertion in the mortises in the clamp *h* strengthen the joint materially. When it is undesirable to show the end grain of the clamp, as at *e*, or of the tenons, as at *f*, the ends of the clamps are mitered off as shown at *g*, and the tenons are not permitted to extend entirely through the clamp.

Tenons and mitered clamps can only be satisfactorily used when the material is thoroughly seasoned, and where the finished product will not be subjected to changes in temperature, as under these connections no provision is made for expansion and contraction.

GENERAL JOINERY.

PROVISION FOR EXPANSION AND CONTRACTION.

20. All joiners' work that is not framed or "built up" should be so fixed that it is free to expand and contract. In a broad surface, such as a plain wainscot, this is accomplished by securing one edge only and permitting the other to rest in a groove, but in such a position that it may

contract as the wood shrinks, or expand when affected by dampness.

All wood is subject to a change in width across the grain, and when both edges are secured, shrinkage will cause the wood to split, and when dampness causes it to swell, it will either bulge in the middle or push the securing nails or screws out of place.

It may here be noted that a thorough knowledge of the properties of various woods is even more important in joiners' work than in carpentry. The slightest tendency of the material to warp, shrink, or swell must be fully compensated or prevented; for, however well seasoned the wood may be, it will always shrink somewhat across the grain when exposed to the warm, dry atmosphere of a dwelling house, and unless properly secured, thin panels will surely warp. For this reason, narrow boards are always to be preferred to wide ones, as the shrinking is distributed over a larger number of joints and is less perceptible; and, if the narrow strips are properly placed with respect to their original position in the tree, the tendency to warp may be largely compensated.

INTERIOR TRIM.

21. It is the work of the joiner to apply the door and window casings, baseboards or skirtings, wainscoting, chair rails, paneled jambs, etc., and to hang the doors, sashes, transoms, etc., which fit into the openings he has trimmed or cased.

Grounds should be placed by the carpenter around the margins of all openings, along the lower edge of the side walls, and wherever necessary to secure any portion of the interior trim.

22. **Architrave** is a term given to a casing, having a back-band, used around door and window openings, and so placed as to conceal the joint between the wood ground and plaster. Thus in Fig. 27 (*b*), *c* is the architrave covering the ground *a* and plaster *b*. Architraves are sometimes

richly molded or elaborately carved, but, except in specially designed work, it is considered better taste to keep them as simple and plain as possible.

23. Where casings extend to the floor, they must be thick enough to receive the end of the skirting *c*, or they may stand upon *plinth blocks a*, as shown in Fig. 21, which project beyond the casings and form both a base to the door trim and a stop for the skirting *c*. The architrave is attached to the ground *a*, Fig. 27 (*b*), after the plastering is thoroughly dry, and is so placed that its outside edge will extend well over and cover the joint between the plastering and the ground.

24. The upper corners of the architrave may be joined in several ways. They may be mitered, as shown at *e*, Fig. 27 (*a*), or, when the surfaces are plain, they may be butted, as shown in Fig. 27 (*f*). When the architrave consists of both plain and molded surfaces, it should be joined by both butted and mitered joints, as shown at (*g*). Sometimes, in cheap work, corner blocks are used to stop the trim against, as shown at (*h*). These, however, are not to be recommended, not only on account of their inartistic appearance, but also on account of their tendency to shrink and leave unsightly cracks on both sides of the doorway. The architraves should be securely nailed both to the ground and to the jamb or lining all around the opening.

25. The **bases** or **skirtings** of a room consist of a band composed of one or more boards from 6 inches to 18 inches wide, running around the bottom of the walls, to protect the plaster.

The skirting board may be plain, or it may have a molding worked on it, as at (*a*), Fig. 14, or it may consist of a plain board with moldings applied independently to give it a finish, as shown at (*b*), Fig. 14.

When the skirting is very wide, and is made up of more than one width of boards, it is sometimes desirable to have the lower member *e* project beyond the upper one, thus

forming a sort of plinth around the room, as shown at *c*, Fig. 14 (*b*). The clearance at *f* should be from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch in rooms which are likely to be carpeted, as the edge

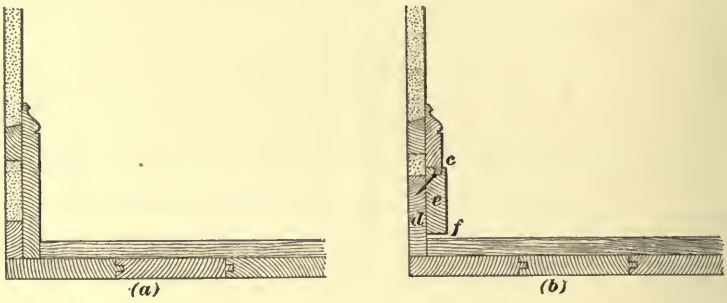


FIG. 14.

of the carpets may then be pushed under it and secured to the floor. When floors are finished with parquet work, etc., the joint between the base and the floor should be as close as possible.

26. Dados and Wainscots.—In some rooms where there is likelihood of much changing of the position of the furniture, such as the dining room, kitchen, library, etc., as well as in the bath room, halls, staircase walls, etc., it is sometimes desirable to affix a broad band or molding against the wall, about 3 feet from the floor and parallel to the skirting, to prevent the backs of the chairs from marring the plaster, and at the same time to form a cap to the dado or wainscot if such is desirable. This chair rail is affixed to a narrow ground, and should, of course, cover the joint between the ground and the plaster. The interval between the chair rail and the skirting is called the *dado*, or *wainscot*. It may be paneled in wood, covered with narrow lining, or simply left plain in plaster.

27. In a paneled wainscot, such as is shown in Fig. 15, great care is necessary in fitting all the joints, and due consideration must be given to the subject of shrinkage, so that the subsequent drying out of the material will not cause

unsightly cracks or open joints. The vertical pieces a, and the horizontal members b, b', and b'', dividing the surface of the wainscot into panels, called stiles and rails, respectively, are framed and glued together. The panels c are left free to shrink or swell to a greater or less extent, without disturbing the surrounding members. The end stiles a' extend from the floor to the top of the top rail b, and are mortised to receive the tenons of the rails b, b', b'', as shown at e, e', and e''. The rails are also mortised, and receive the tenons of the short stiles, or muntins a, a'', as shown at f.

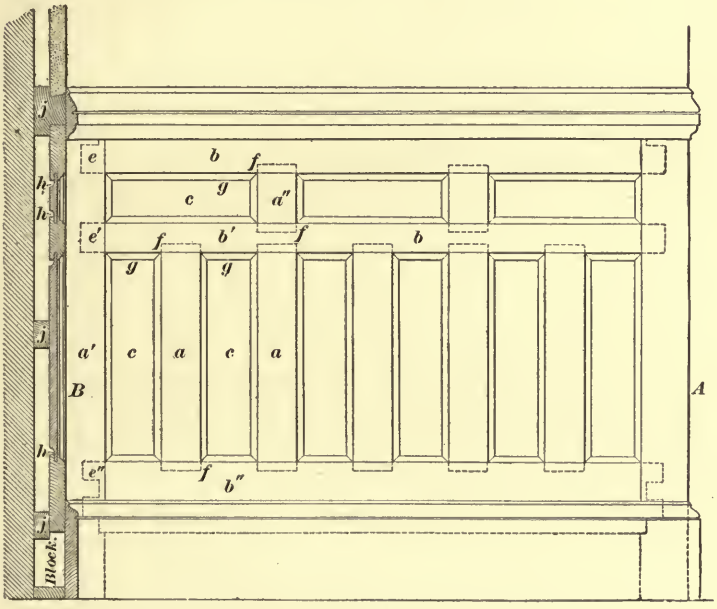


FIG. 15.

In the edge of each stile and rail a groove is worked to the depth of the molding g, and the edges of the panels c are beveled off or hollowed out and inserted in this groove, as shown at h. The moldings g when small may be worked on the edges of the stiles and rails, but when large and heavy they must be worked from separate stock and fitted in position afterwards.

The panels are thus practically separate from the surrounding frame, and are free to shrink without danger of splitting. At the same time, since the amount of cross-grain in the extent of the wainscot is equal only to the sum of all widths of the stiles in one direction and to all the widths of the rails in the other direction, the shrinkable material is reduced to a minimum, so that the wainscot, when constructed with well seasoned material, will give good results.

28. Where the face of the wainscot is to be a plain unpaneled surface of wood, still further precautions must be taken to guard against the effects of shrinkage. Two general methods are recognized as satisfactory for the purpose of securing these large surfaces of work against the effects of warping and shrinking. One is to make the wainscot of narrow boards, not more than three times their thickness in width, and with the grain reversed in every second piece—that is, to have the heart side of the material show on each side at every second board. After being tongued-and-grooved and glued together, the boards are secured against warping by means of keys inserted as described in Art. **18.**

Another method is to build the wainscot with several thicknesses of thin stock, reversing the grain in each piece. This method is the better one for long, unbroken surfaces, as its shrinkage is prevented almost entirely; but, when the design of the wainscot will permit the building of a stile or pilaster every 6 or 8 feet, the narrow, keyed boards will be found to serve very satisfactorily, if a $\frac{1}{2}$-inch space between the ends under the pilasters is left to provide room for expansion and contraction. These keyed sections, if the grain runs vertically, should be secured to the wall only in the center of their lengths, and left loose the rest of the way to come and go with atmospheric changes. If the grain runs lengthwise of the wainscot, no stiles or pilasters will be required to cover the joints, as the wainscot can be built up of one continuous piece; but the shrinkage must be provided for between the base and the coping, or surbase, and the

wainscot secured only in the center of its height, so as to allow the top and bottom to come and go.

29. After the paneling of the wainscot is completed, it is secured to the grounds, shown at *j*, Fig. 15, which were set in place to receive it, before the plastering was applied. Every possible precaution must be taken to insure the drying of the plaster, as the presence of the slightest moisture is fatal to permanent joiners' work. Under the most favorable conditions, there should be allowed at least a week to dry each of the first two coats of plaster, and the hardwood trim should not be applied for two weeks after the finished coat is spread. In damp or rainy weather much more time should be allowed. The patent prepared plasters and wall cements take less time than this to dry, and a deduction can be made when these are used, according to the rapidity of their drying, as described in *Masonry*.

30. When the wainscot is secured horizontally through its center, and allowed to shrink at the top and bottom, a horizontal ground must be provided to nail it to, and additional grounds must be provided at top and bottom to secure the coping and the base, as well as to form a backing for the upper and lower edges of the dado.

When the wainscot is secured along vertical lines every 8 or 10 feet of its length, vertical grounds must be provided, in addition to the grounds at top and bottom, as above described.

31. In laying out and spacing the stiles, rails, and panels of a wainscot, it is first necessary to prepare a long measuring rod, about 2 inches wide, through the center of which a line is drawn, as shown at *a b* in Fig. 16. The rod is then divided into a number of spaces, corresponding with the widths of the stiles and panels on one side of the line, and with the width of the rails and length of the panels on the other side. That is, the divisions in Fig. 16 which are above the line *a b*, as *c d*, *l m*, *l' m'*, etc., show the location and widths of the stiles *a* in Fig. 15, while the large divisions, as *d l*, *m l'*, etc., show the width of the panels *c*.

The divisions *e f*, *g h*, and *i k* below the line *a b* mark the widths of the rails *b*, *b'*, and *b''* in Fig. 15, and the spaces *f g* and *h i* show the width and length of the panels.

The three rails *b*, *b'*, *b''* are clamped together with hand screws, and the rod is then used to lay out the width of, and spacing between, the stiles; these divisions are then squared across the three rails with a square, and marked with a scratch awl or the point of a knife. The stiles are then marked in the same way, three or four at a time, and an allowance is made for the length of the tenons on the ends. In laying out the measuring rods for the spacing of the stiles and panels, it must be remembered that a stile must

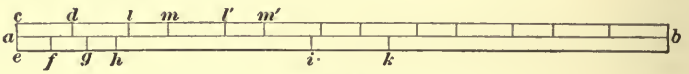


FIG. 16.

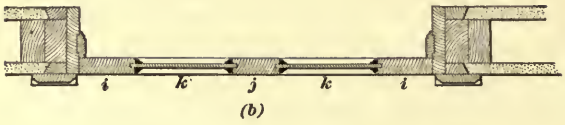
exist on each end of the wainscot; and to determine the number of panels required, the width of one stile and twice the thickness of the wainscot must be subtracted from the length of the room, if the wainscot returns on two interior angles, and the remainder is divided by the sum of the widths of one panel and one stile. If, however, the wainscot returns around one exterior and one interior angle, as at *A* and *B* in Fig. 15, the width of one stile only should be deducted.

32. In Fig. 15, the length of the wall along which the wainscot is built is 3 feet 11 inches and the panels are each $4\frac{1}{2}$ inches wide; the stiles are all 3 inches wide, except the end one *A*, which is $3\frac{1}{2}$ inches wide. If we now subtract $3\frac{1}{2}$ inches, the width of the end stile, from 3 feet 11 inches, the length of the wall, we have 3 feet $7\frac{1}{2}$ inches of wainscot to be divided into six equal panels and six equal stiles. The combined width of a panel and stile is, therefore, $43\frac{1}{2}$ in. $\div 6 = 7\frac{1}{4}$ inches. Since the stiles are to be 3 inches wide, then $7\frac{1}{4} - 3 = 4\frac{1}{4}$ inches is the width of each panel opening. If the wall at *A* had returned on an interior angle, like the wall at *B*, we would have the end stile at *A*

of the same width as the stile at B, and we would then have deducted 3 inches, the width of one stile, $+2\frac{1}{4}$ inches, twice the thickness of the wainscot, from 3 feet 11 inches, which would give us about $6\frac{3}{32}$ inches as the width of each panel and stile combined; and, allowing 3 inches for the stiles, each panel opening would be $3\frac{3}{32}$ inches in width. The panels themselves, however, will be wider than that, as a proper allowance must be made all around for their insertion in the groove, as shown at h.

33. After all the mortises and tenons are cut and fitted, and each has been marked so that it can be returned to the same place to which it was fitted, the pieces of wainscot are taken apart and laid in a pile preparatory to gluing. Only the shoulders and faces of the mortises and the shoulder ends of the tenons receive the glue, and the stiles are forced into the rails as soon after the glue is applied as possible. The lower stiles are glued in the bottom rail first, then their upper tenons are covered with glue in the same manner, and the middle rail b' is forced over them. The upper stiles are then glued into the middle rail; and finally the top rail b is glued in place, and the whole form is drawn together with bench clamps until the glue is thoroughly dry.

34. In all joiners' work, framed together with mortise and tenon, care must be taken to clean out the mortises thoroughly, and dust off the tenons before gluing; each tenon must be tried in the mortise to which it belongs and any unevenness removed, to insure its proper fit. All framed work should have its parts heated thoroughly before being clamped and glued together. If, when a piece of work is being clamped up, any rail or stile has a tendency to warp, then that rail or stile must be clamped in place with a bench screw under a piece of thick plank, and must so remain until the glue is dry. Care must always be taken that an extreme pressure of the clamps does not cause the work to deflect or wind, as it is exceedingly important in all kinds of paneled work that the whole face of the frame be kept in place, out of wind, until the glue is thoroughly set or dry.



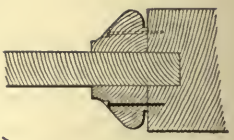
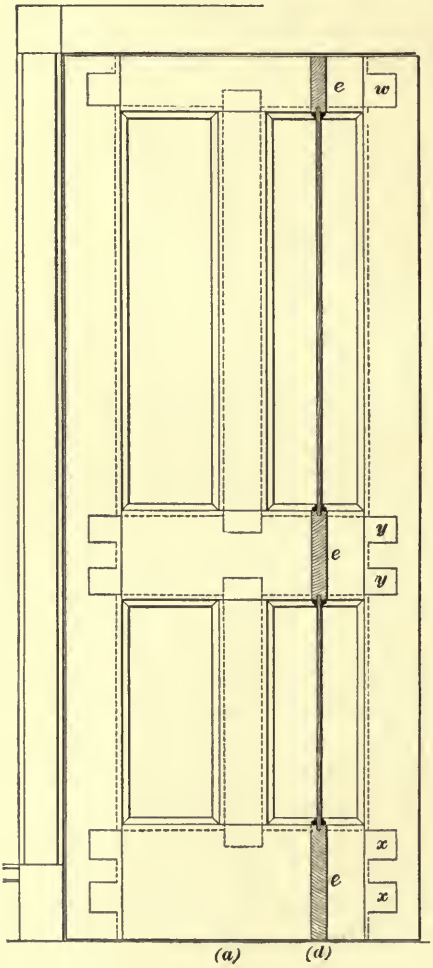


FIG. 19.



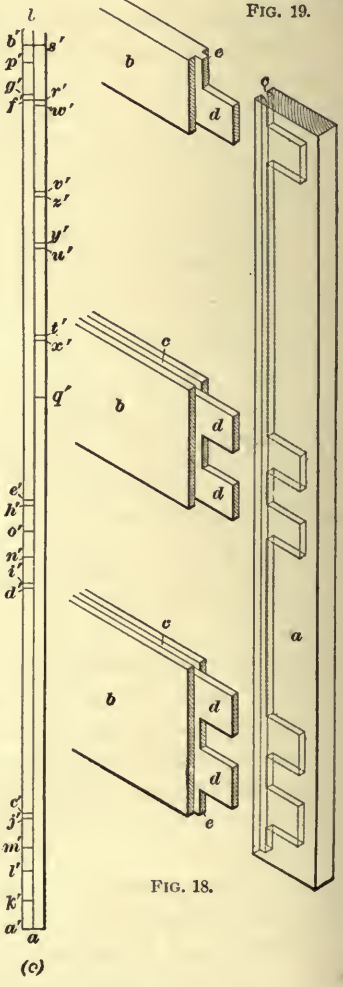


FIG. 18.

FIG. 17.

DOOR MAKING.

35. A door is a simple piece of paneled work, but the great variety of form and arrangement of its panels, and the enrichment of its moldings, together with the conditions arising from its method of opening or closing, require it to be even more securely framed and glued than a wainscot or other piece of fixed paneled work.

The swinging of a door on its hinges brings a great strain on the joints in the stile on the hinge side, whereas a sliding door hung from the top has its entire weight brought upon the joints of the top rail, or, where hung from the stile, the conditions are the same as with a hinged door.

36. In Fig. 17 (*a*) is shown a simple four-paneled door which, though devoid of any complicated framing, may be taken as a type of all doors, no matter what may be their specific design.

In laying out a paneled door, a measuring rod is first prepared, in the same manner as for a wainscot. This rod is shown in Fig. 17 (*c*), where on one side of the line $a\,b$, gauged down the middle, is laid off the distance $a'\,c'$ equal to the width of the bottom rail of the door. Then the distance from the bottom of the door to the top of the middle rail (or lock-rail, as it is called) is laid off at $a'\,e'$, and from e' is measured down the width of the lock-rail $e'\,d'$. Next the whole height of the door is laid off on the rod from a' to b', and from b' is measured down the depth of the top rail $b'\,f'$.

As the stiles are grooved to receive the panels, a distance of $\frac{1}{2}$ inch is laid off from the upper side of the bottom rail at $c'\,j'$, from the under side of the top rail at $f'\,g'$, and from both sides of the lock-rail at $e'\,h'$ and $d'\,i'$; then we have $j'\,i'$ as the length of the lower panels and $h'\,g'$ as the length of the upper panels.

On the bottom rail $a'\,c'$, we have two tenons $k'\,l'$ and $m'\,j'$, each $2\frac{1}{2}$ inches wide, with $1\frac{1}{2}$ inches between them, and also $1\frac{1}{2}$ inches between the lower tenon $k'\,l'$ and the bottom of

the rail. The space between these tenons at $l'\,m'$ and $a'\,k'$ is provided with a short projection which passes into the stile to the bottom of the groove. This projection is called a *relish*, and its purpose is to preserve some solid wood in the groove between the mortises. The double tenons are necessary in the wide rails in order to preserve the strength of the stiles.

On the lock-rail $d'\,e'$, the width of the tenons is laid off at $i'\,n'$ and $o'\,h'$ with a relish preserved at $n'\,o'$. The tenon of the top rail is marked at $g'\,p'$, and $p'\,b'$ is left for the relish; $c'\,d'$ is then the length of the lower muntin between the shoulders, while $c'\,f'$ is the length of the upper muntin.

On the other side of the rod, at $q'\,s'$, are laid off the proportions for the division of the widths; thus $q'\,t'$ and $s'\,w'$ are each equal to the width of a stile, and exactly midway between these is laid off, at $u'\,v'$, the width of the muntin, and $y'\,z'$ is the width of the muntin at the bottom of the grooves to receive the panels. The widths $t'\,x'$, $u'\,y'$, $v'\,z'$, and $w'\,r'$ are $\frac{1}{2}$-inch allowances for the grooves in the stiles and muntins, and at $x'\,y'$ and $z'\,r'$ is shown the extreme width of the panels. The mortises and relishes are also here shown as on the other side of the rod.

37. A horizontal section of this door and trim, showing the details of construction, is shown in Fig. 17 (*b*). At i, i are shown the stiles laid off on the measuring rod at $q'\,t'$ and $w'\,s'$, and at j is the muntin marked on the measuring rod at $u'\,v'$; k, k are the panels inserted in the grooves of the stiles and muntin, which grooves were provided for on the measuring rod at $x'\,t'$, $u'\,y'$, $z'\,v'$, and $w'\,r'$.

A vertical section of the door is shown in Fig. 17 (*d*), where e, e, e are the three rails, grooved as provided for on the measuring rod. The elevation of the door, Fig. 17 (*a*), shows the tenons of the bottom rail where they enter the mortise of the stile at $x\,x$, the tenons of the lock-rail at y, y, and the single tenon on the top rail at w. The dotted lines show the grooves in the stiles, rails, and muntins, and the relishes between and beyond the tenons.

At *a*, Fig. 18, is shown a perspective view of one of the stiles; at *b*, *b*, the ends of the rails; at *c*, *c*, the grooves for the panels and relishes; and at *d* and *e*, the tenons and relishes.

38. When the measurements for the door are all laid out on the rod, the stiles and rails for all doors of one pattern are cut out of well seasoned stock of proper thickness, and each member is then carefully planed and marked on its *jointed edge*. The rails are cut to their full lengths including tenons, and the stiles are cut about 4 inches to 6 inches longer than is required; when all the rails and stiles are cut, a set for one door is then taken, and the grooves for the panels are plowed as shown at *c*, Fig. 18. The mortises and tenons are cut and accurately fitted one at a time, and each is marked for the place for which it is intended. Or, where a number of doors are exactly alike, a half dozen or more rails or stiles of one kind may be taken, placed side by side, clamped tightly and marked for their respective mortises and tenons at one operation. The door now having been made and the tenons carefully fitted to their respective mortises, the door is put together without glue or other fastening, and left until immediately before it is required to be fixed in the building, in order that it may have as long a time as possible to season.

Before being glued, the door is taken apart, the mortises are cleaned, the tenons are spread with glue on their shoulder ends, and after the panels are inserted the whole is driven close with a heavy mallet, laid on a pair of trestles, and secured, until the glue is dry, by means of bench clamps, one of which is placed opposite each rail.

39. In strictly first-class work, the mortises and tenons do not extend entirely through the width of the stile, but are let in from only $\frac{2}{3}$ to $\frac{3}{4}$ the width, as shown at *w*, *x*, and *y*, Fig. 17 (*a*). But, in cheaper work and in some "machine-made" doors, the tenons extend entirely through the stile and are wedged up from the outside to render them tight. In such cases, the mortise is made from $\frac{1}{4}$ to $\frac{1}{2}$ inch larger on

the outside than on the inside, and the tenon is then, by means of a couple of wedges, expanded to a dovetail form. Sometimes the wedges are driven above and below the tenons, and are glued in place to make the whole joint tight and secure.

40. The proportions of the panels, and the details of the design of the panels and moldings of doors, are subject to great variation. The lock-rail, however, should always be in a position not too low for one to be able to reach the lock without stooping, nor too high for a person to grasp the knob without reaching. The standard height to the center of the knob of the lock has been fixed at 3 feet from the floor. The lock should be mortised into the stile *between* the tenons of the lock-rail, or immediately above them, in

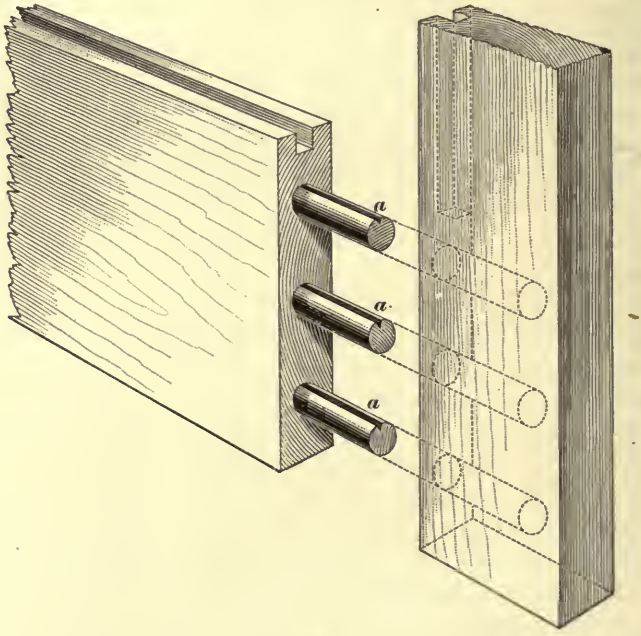


FIG. 20.

order not to destroy these tenons when the lock is inserted. A preferable method is to put in a lock-panel from 6 inches

to 7 inches wide in place of the lock-rail; this is accomplished by practically cutting the lock-rail in two in the width and inserting a panel between the sections, as shown in Figs. 21 and 22.

41. The moldings around the panels of doors may be a simple ogee, worked on the edges of the stiles and rails, or they may be inserted in the angle between the edge of the stile or rail and the panel, as shown in Fig. 19, care being taken to see that the nails pass into the edges of the framing (and not into the panels), as suggested in the figure.

42. In some foreign countries, and in certain localities of America, the stiles and rails of panel work are put together with dowels, as shown in Fig. 20. These dowels vary from $\frac{3}{8}$ inch to 1 inch in diameter, according to the thickness of the wood to be united, but in any case they are considerably thicker than a mortise would be in the same material. Along the edge of each dowel, a **V**-shaped groove is cut, as shown at *a*, to allow the air and surplus glue to escape when the parts are driven together.

43. **Sliding doors** differ from ordinary swing doors chiefly in the method of hanging them, and, as the strain of their parts is reduced or increased with the different methods, a corresponding alteration of the details of their framing is necessary. Fig. 21 (*a*) shows one of a pair of sliding doors, which is intended to be hung from the top, as the stile is not then subjected to as great a strain as when the door is hung on the side. Where a sliding door is hung with the patent stile hanger, which brings the entire weight upon the stile, particular attention must be given the mortises and tenons in the hanging stile to insure their perfect fit, as the slightest loosening would cause a sag in the door, which would prevent it from running smoothly.

In the plan of this door, shown at (*b*), the meeting rails of both doors are shown, and, as will be seen, the edges of the rail are worked to fit together in a shallow tongued-and-grooved joint. This preserves the alinement of the doors

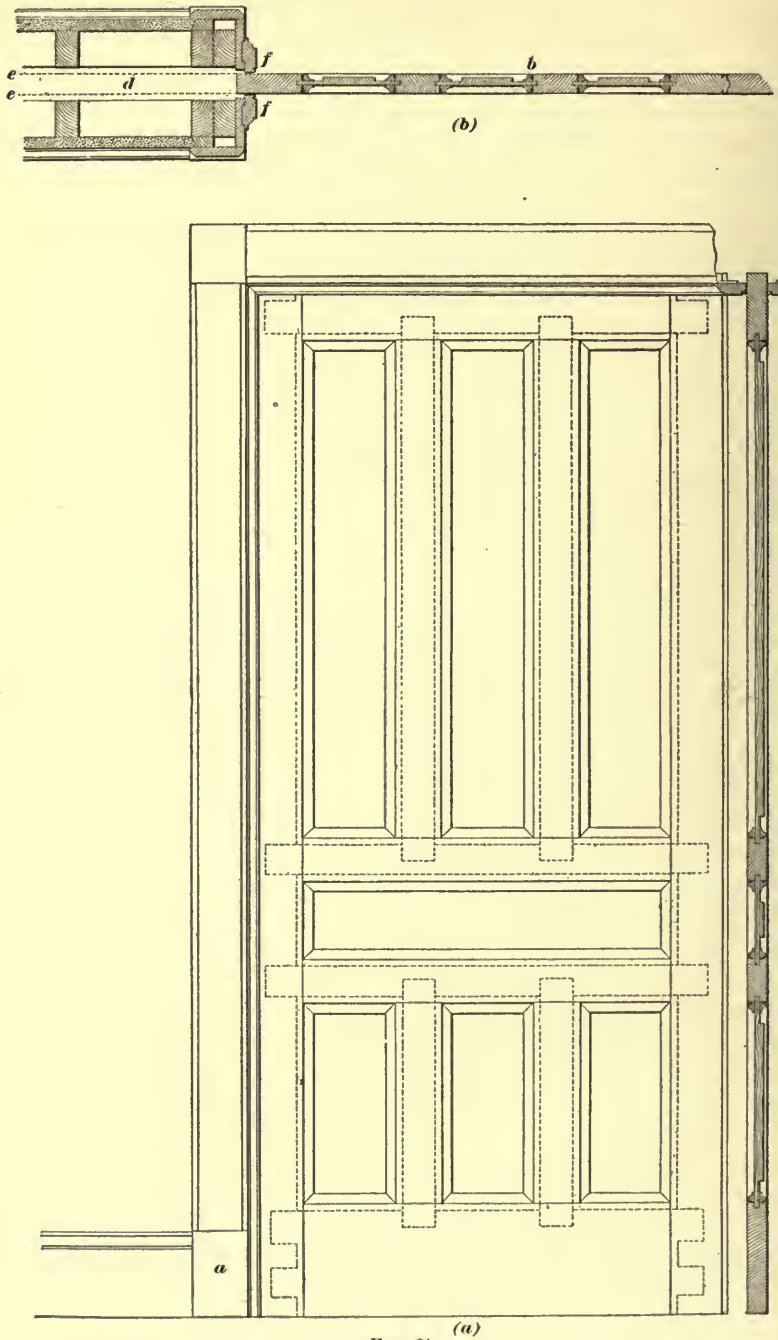
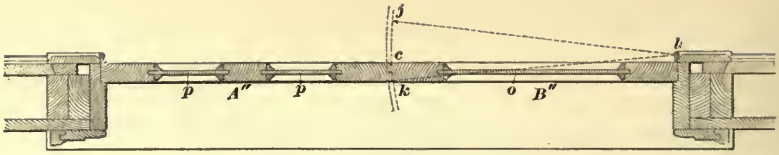


FIG. 21.

when closed, and tends to prevent the appearance of a slit, or crack, between them, as would be the case if they simply butted together.

In opening, the doors slide into a pocket built in the partition, as shown at *d*, the dotted lines *e* showing the position of the door when it is in the pocket. This pocket is framed and finished in the same manner as a simple studded partition, except that the studs are set in two rows with a space between them, at *d*, about $1\frac{1}{2}$ inches to 2 inches wider than the door is thick. The jambs of the door opening are then finished with a molded trim, which is let into the jamb, as shown at *f*, and is allowed to project over the end of the pocket to within $\frac{1}{4}$ inch of the door. A stop is provided within the pocket *d*, to prevent the door from sliding too far into the opening. The hardware on the meeting stiles of the door must be sunk flush with the face of the stile, so that it will not prevent the door from sliding clearly into the pocket. Numerous sliding-door locks and catches are provided by the hardware dealers, made specially for this style of door.

44. Folding doors consist of a pair of single doors hinged on opposite sides of the opening, and provided with a stop-bead or rabbeted stile, so that they will close together in a tight joint at the middle of the opening. Fig. 22 shows a plan (*a*) and an elevation (*b*) of a pair of folding doors which are arranged to meet the requirements of the outside vestibule-entrance doors, or storm doors as they are sometimes termed, of a frame dwelling. When this form of door is used as an inside vestibule door or a direct-entrance door, the panels *b*, as shown at *o* in the section *B″*, taken on the line *B B′* of the elevation, are usually of glass, but in the former case the transom only may be glazed, to admit light to the vestibule when both doors are closed. The sectional plan *A″* of the door is taken on the line *A A′*, and shows the two lower panels at *p*. The framing of the stiles and rails of folding doors is precisely the same as for single swing doors, but the meeting rails must



(a)

(b)

FIG. 22.

be rabbeted, as shown at *c*, so as to provide a stop against which the more frequently used door may close.

This rabbeted stop must be beveled off slightly on the inside, to give proper clearance to the outside angle of the door when it is opened. The amount of bevel necessary in order to accomplish this clearance is found by striking a circular arc *j k* with a radius *k l* equal to the diagonal distance from the corner *k* of the door to be cleared to the center of the butt pin *l*, and with a center at the latter point.

WINDOWS.

45. In the construction of a building, openings are left in the walls which are subsequently to be provided with some form of window frame and sash. The particular form in each case will depend upon the character of the building and the purposes for which the windows are required. In residence structures, the main object is to secure proper light and ventilation, and some form of sash window is used; while in stores and some warehouses, the first-story windows are usually arranged for the display of goods exposed for sale, and the window assumes the character of a glass case without sashes or frames, except such as are necessary to hold the glass in place.

46. Sash windows may be divided into two general classes, namely, *fixed* sashes and *movable* sashes, and the latter class may be hinged, pivoted, or balanced, as the case may require. Window sashes vary in thickness according to their size, but in ordinary frame dwellings they seldom exceed $1\frac{3}{4}$ inches. The frames for these windows are generally built in the walls as the building is carried up, and are differently constructed, according to the character of sash they are to carry and the material of the wall in which they are inserted.

47. In Fig. 23 is shown the construction of a window frame for an ordinary frame dwelling. At (*a*) is the section through one side of the frame showing the stud at the side

of the opening at *a*, the exterior sheathing at *b*, and the lath and plaster on the interior at *e*. The pulley stile *g* is set from 2 to 2½ inches away from the stud *a*, to provide room for the sash weights *i*. At *f* is the exterior sash stop, against which is secured the exterior casing or blind-hanging stile *c*, which must be of the same thickness as the blinds. The exterior sheathing *b* is cut flush with the inside of the stud opening, as explained in *Carpentry*. The casing *c* is then also secured to the stud *a*, through the sheathing *b*, thereby keeping the pulley stile in its place on the outside, while the architrave, or interior casing *j* performs the same function on the other side of the wall. The pulley stile *g* is plowed for the parting bead *h*, and in the groove thus formed, the ½ in. × 1 in. parting bead *h* is inserted as shown, forming a channel for the upper sash to slide in. The lower sash is hung on the inside of this parting bead, and is secured in place by a *stop-bead n* 1½ inches wide and ½ inch thick. The stop-bead and parting bead are not secured in place on the pulley stile by means of nails or glue, but are left so that either may be readily removed and the sash may thereby at any time be taken out if required. The parting bead is kept in place simply by the tightness of its fit in the groove in the stile, and by the meeting rails of the sashes, which are fitted around it, as described hereafter. The stop-bead is screwed to the casing, and can be easily removed at any time if desired.

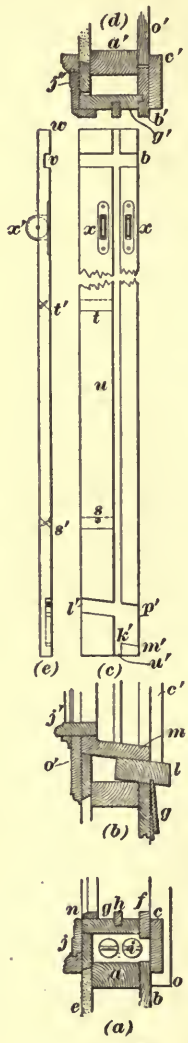


FIG. 23.

48. At (*b*) is shown a vertical section of the frame through the sill, and other details of the lower part of the window. The sill *m* is inclined at a pitch of

about $1\frac{1}{2}$ inches to the foot, and its outer edge rests upon the 2-inch sub-sill *l*, which is inclined at a similar angle, and has its under side grooved to receive the upper edge of the clapboards *g* or shingles covering the side of the house. At *o'* is shown the inside casing, or *apron*, as it is frequently termed, which is attached to the back of the sill *m*, and which with the sill cap forms the inside finish of the lower part of the window. The inside casing, or architrave, *j'*, as shown in the sectional plan at *j*, rests upon the sill cap. The sub-sill *l* is the detail that forms the bottom of the window on the outside of the house; upon it rests the exterior casing *c'*, which is seen in the sectional plan at *c*, and which frames the window opening on the outside, in the same manner as does the trim *j'* on the inside. The sill and sill cap are both carried beyond the casings *c* and *j*, and are returned around them and against the walls, as shown at *o* in the plan (*a*).

49. At (*c*) is shown the elevation of the inside face of one of the pulley stiles. The lower part of the pulley stile *l' m'* is cut out to receive the ends of the sill and sub-sill—the sill extending through the entire thickness of the stile from *l'* to *p'*, and the sub-sill extending from *k'* about 2 inches beyond the face of the stile at *m'*. The $\frac{1}{2}'' \times \frac{1}{2}''$ groove plowed to receive the parting strip *h*, is shown at *u*. The depth of the cut-out portion *l' p' m' k'* is equal to the depth of the groove *u*, and as shown at *u'*, the groove extends to the bottom of the stile. The upper part of the pulley stile is grooved at *b* to receive the window head, immediately below which are placed the two pulleys *x*, *x*, one for each sash. These pulleys are let into the face of the stile so that the face plates are flush with the inside of the frame, but the wheels extend through to the interior, as shown at *x'*, in the side elevation (*e*) of the stile. The depth of the groove to receive the window head is $\frac{1}{2}$ inch, as shown at *v*; the material from *v* to *w* extends 2 inches above the window head, to permit the fitting of the frame to the stud opening.

At *s t* in the elevation (*c*) is shown an opening to the weight box known as the *pocket*. This opening is cut out to permit

easy access to the weights, in case of renewal of the sash cords, and is closed by means of a bevel-edged board secured in place by screws. In the elevation of the pulley stile at (*e*), the pocket cover is shown at *s' t'*, as well as the lines on which the ends are beveled to secure the desired fit. The upper bevel at *t'* is notched over the shank and under the head of a screw inserted in the back of the stile, as shown at *t'*. The lower bevel *s'* is then secured against the bevel of the pocket by means of a screw driven straight through the face of the cover, as shown at *s* in the elevation (*c*).

50. At (*d*) is shown a section through the window head at the center of the opening. Here the stud *a'* is shown in its position at the top of the frame opening, while the window head *g'* is shown 2 inches below; these 2 inches permit projections of the stiles, shown in (*e*) at *v w*, to be fitted to the top of the opening. The inside trim *j''* is then secured across the opening between the casing *g'* and the stud *a'*, and the outside trim *c'* is laid over the exterior casing *b'* and extends to the sheathing at the edge of the framed opening

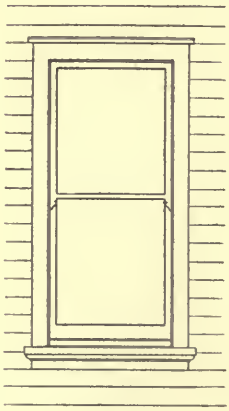


FIG. 24.

FIG. 25.

at *o'*. A cap member should be placed over the upper edge of the casing to shed the water, or a cap flashing of copper or lead may be used.

This practically completes the description of the details of the frame for any single window in a frame building such as shown in Fig. 24; when, however, windows are coupled in pairs or triplets, a dividing member, called a *mullion*, must be included in the frame, as shown at *a* in Fig. 25.

51. A **mullion** is simply a division placed between two sashes. With sliding sashes it must contain the weight box for their inner edges, but with hinged sashes it need be no more than a bar, against which the sashes may close, and upon which they may be hinged. The former kind is illustrated in Fig. 26, which shows a horizontal section through the mullion *a* in Fig. 25.

Inasmuch as the mullion may contain four weights (two for each pair of sashes), instead of two weights as in the box of a single window, the inside trim *a* and the outside trim *c* must be somewhat wider than the same details are in a single frame.

The pulley stiles *b*, the stop-beads *c*, and the parting strips *a* are detailed in precisely the same manner as in a single frame, but the distance between the stiles *b* being from 4 to 5 inches, in order to accommodate the weights *d*, the casings require to be proportionately wider to cover the joints. The pocket in the pulley stile may exist on one side of the mullion only, as access to all four weights can thereby be readily attained. The sill of the window, however, is not gained into the pulley stile of the mullion, as is the case with the single frame shown in Fig. 23. Instead, the sill and the window head each extend as one piece across both openings, and each is grooved to receive the mullion pulley stiles.

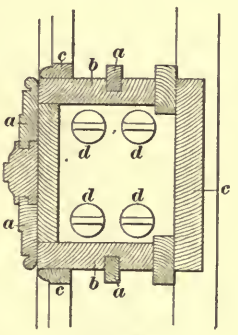


FIG. 26.

52. When a window frame is required for insertion in the opening of a brick or stone wall, the details shown in Fig. 23 must be considerably altered in order to make the

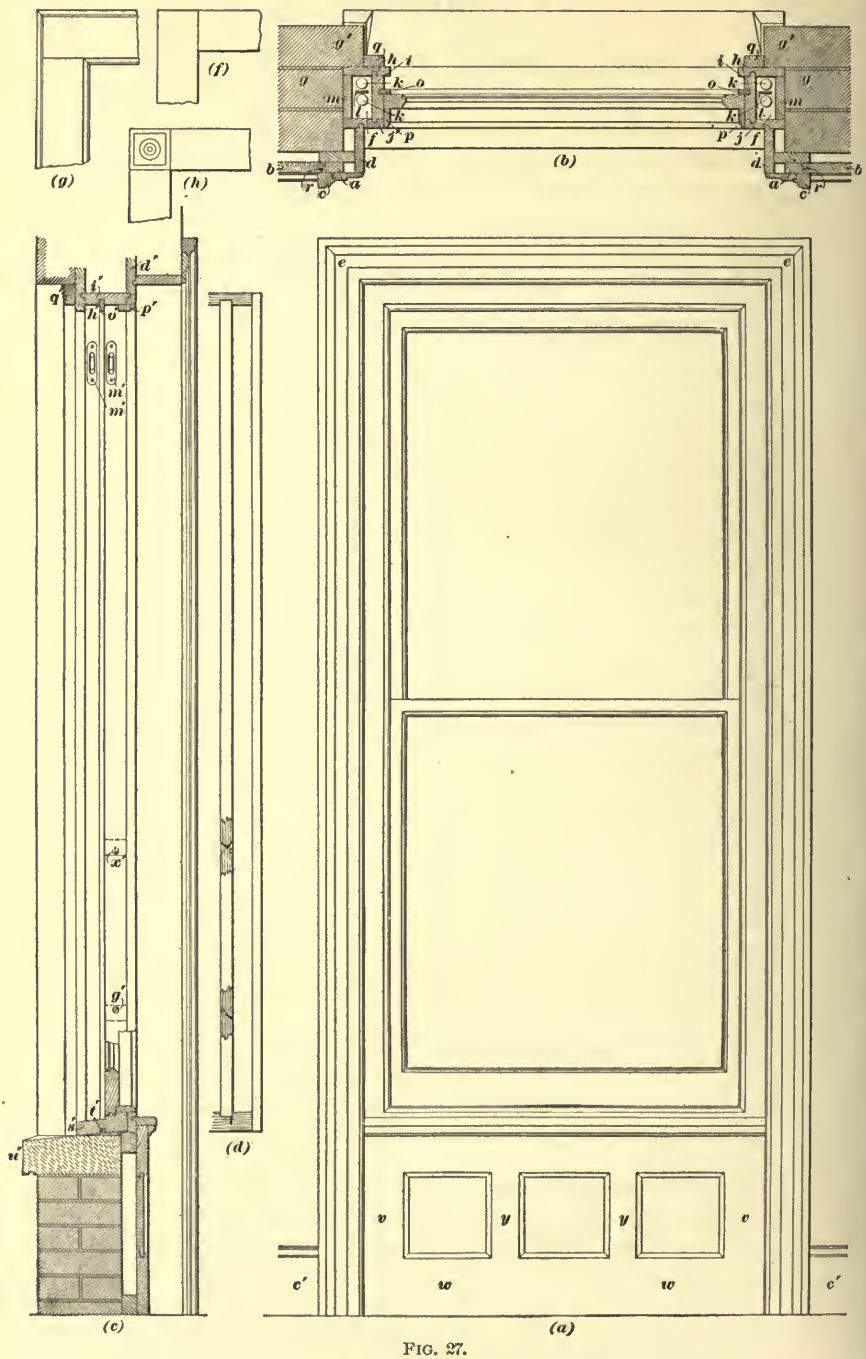


FIG. 27.

frame fulfil the requirements. Fig. 27 shows at (*a*) the interior elevation of such a window; at (*b*), a horizontal section; at (*c*), a vertical section; and at (*d*), a section through one of its pulley stiles. In the horizontal section (*b*) the weight boxes with the details of their construction are shown at *f*. The brick wall *g* is 12 inches thick, with a reveal at *g'* of 4 inches. At *h* is shown the outside lining, into a groove of which is tongued the pulley stile *i*, which in turn is, in a similar manner, let into the inside lining *j*. These three pieces form a box *f*, in which are hung the two sash weights *k*, separated by a wooden tongue *l*, to prevent them striking together when the sash is raised or lowered. The weight box is closed by the back lining *m*. The pulley stile *i* is grooved to receive the parting bead *o*, which, with the $\frac{1}{2}$-inch or $\frac{5}{8}$-inch projection of the outside lining *h*, secures the upper sash in its place and provides a *way* in which it may slide. The parting bead may be of hardwood from $\frac{1}{2}$ in. $\times$ 1 in. to $\frac{5}{8}$ in. $\times 1\frac{1}{4}$ in. section. The lower sash slides inside of the parting bead and is secured in place by means of the stop-bead *p*.

In the angle between the outside lining *h* and the brick reveal *g'*, is placed a casing *q* to which outside blinds or shutters may be hung, though sometimes it is of some special design. The jamb lining *d* is secured to the inside lining *j*, and extends to the floor; the architrave, or trim *c*, is attached to it, and by covering the ground, binds the plaster joint at *r*.

The top of the window frame is shown in Fig. 27 (*c*). Here the exterior casing or angle mold is mitered in the corner and is carried across the top of the window as shown at *q'*, while the outside lining is butted in the corner and carried across the top of the opening, as shown at *h'*. The window head *i'* is let into the pulley stiles and plowed to receive the parting strip *o'*. The stop-bead *p'* is mitered in the angle and returned across the top of the frame, covering the joint between the window head *i'* and the inside casing *d'*. The pulleys *m'* are the same as in the former case, and the pocket, as shown at *x' g'*, gives access to the weights.

The sill s' in this case rests its outer edge on the stone sill u' instead of on a wooden sub-sill, as in the previous example. There is also a break or step in the thickness of the sill where the stop-bead meets it. When set, the sill is laid on a bed of mortar spread over the stone sill u', and this mortar, being forced up into the groove shown at t', makes a perfectly water-tight joint between the two sills.

From the sill to the floor, on the inside of the window, the wall is covered by a *panel back*, or breast, as shown in the elevation (a) at w. The stiles, rails, and muntins of this panel back are grooved on their edges and mortised and tenoned together, as are also the same details in the doors. The lower rail is scribed to the floor, and the upper rail is capped by the wooden sill of the window, as shown in the section (c). A molding is then set into the angle between the sill of the window and the rail of the panel back, and finishes the joint. The stiles of the panel back are considerably wider than those shown at (a), as they extend beyond and behind the jamb lining.

53. Sashes vary slightly in their construction, according to the manner in which they are hung, and the character of the building for which they are intended. Sashes of ordinary dimensions are from $1\frac{1}{2}$ inches to 2 inches in thickness, with the bottom rail $3\frac{1}{2}$ inches to 4 inches in width, while the stiles and top rail are 2 inches in width. The meeting rails of double-hung sashes are usually $1\frac{1}{2}$ inches wide, and are beveled, as hereafter described, to insure a tight joint.

Sashes which are to be glazed with heavy plate glass should be at least 2 inches thick, and should have a bottom rail 4 or 5 inches wide.

The outside dimensions of window sashes are dependent very largely upon the regular market sizes of glass, it being economical to use glass in sizes that can be procured without cutting to waste.

A table of the sizes of window glass and the number of panes in a box is given herewith; a box being supposed to contain 50 square feet of glass.

TABLE OF SIZES AND NUMBER OF PANES IN A BOX OF WINDOW GLASS.

Size in Inches.	Panes in Box.	Size in Inches.	Panes in Box.	Size in Inches.	Panes in Box.	Size in Inches.	Panes in Box.
6×8	150	12×19	32	16×20	23	24×44	7
7×9	115	12×20	30	16×22	20	24×50	6
8×10	90	12×21	29	16×24	19	24×56	5
8×11	82	12×22	27	16×30	15	26×36	8
8×12	75	12×23	26	16×36	12	26×40	7
9×10	80	12×24	25	16×40	11	26×48	6
9×11	72	13×14	40	18×20	20	26×54	5
9×12	67	13×15	37	18×22	18	28×34	8
9×13	62	13×16	35	18×24	17	28×40	6
9×14	57	13×17	33	18×26	15	28×46	6
9×15	53	13×18	31	18×34	12	28×50	5
9×16	50	13×19	29	18×36	11	30×40	6
10×10	72	13×20	28	18×40	10	30×44	4
10×12	60	13×21	26	18×44	9	30×48	5
10×13	55	13×22	25	20×22	16	30×54	5
10×14	52	13×24	23	20×24	15	32×42	5
10×15	48	14×15	34	20×25	14	32×44	5
10×16	45	14×16	32	20×26	14	32×46	5
10×17	42	14×18	29	20×28	13	32×48	5
10×18	40	14×19	27	20×30	12	32×50	4
11×11	59	14×20	26	20×34	11	32×54	4
11×12	55	14×22	23	20×36	10	32×56	4
11×13	50	14×24	22	20×40	9	32×60	4
11×14	47	14×28	18	20×44	8	34×40	5
11×15	44	14×32	16	20×50	7	34×44	5
11×16	41	14×36	14	22×24	14	34×46	5
11×17	39	14×40	13	22×26	13	34×50	4
11×18	36	15×16	30	22×28	12	34×52	4
12×12	50	15×18	27	22×36	9	34×56	4
12×13	46	15×20	24	22×40	8	36×44	5
12×14	43	15×22	22	22×50	7	36×50	4
12×15	40	15×24	20	24×28	11	36×56	4
12×16	38	15×30	16	24×30	10	36×60	3
12×17	35	15×32	15	24×32	9	36×64	3
12×18	33	16×18	25	24×36	8	40×60	3

54. Large plate-glass windows are usually designed to have the sash pivoted at the center of the top and bottom

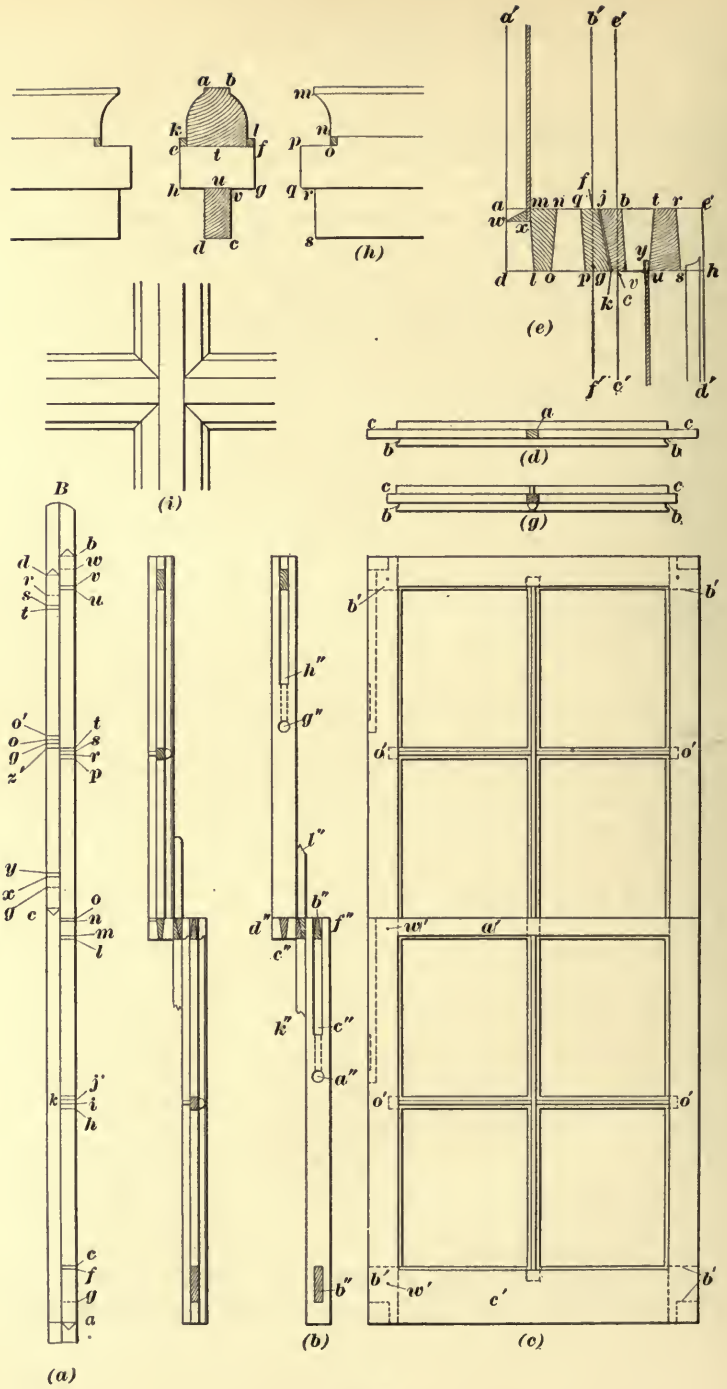


FIG. 28.

rail, if the sash is for one pane, and is too heavy to balance with weights; or, if a muntin or pair of meeting stiles down the center is not an objectionable feature, the sash may be of the form known as the French casements, where the two sashes are hinged to the frame and meet and lock together in the middle like a pair of folding doors.

55. Sash making, like all framed work in joinery, is preceded by the preparation of a measuring rod, upon which are laid out the various dimensions. Fig. 28 shows a pair of sashes for a double-hung window, the lights of which are to be 8 in. $\times$ 10 in. A rod of proper length, as shown at (*a*), is first prepared as follows: On one side of the central dividing line is laid off the distance *a c*, equal to the width of the bottom rail, which in this case is $3\frac{1}{2}$ inches. From *e* to *f* is then laid off $\frac{3}{16}$ inch for the rabbet, and from *f* to *i* is measured $10\frac{1}{16}$ inches for glass; *i h* is then laid off $\frac{3}{16}$ inch for rabbet, and *h k* is laid off $\frac{1}{2}$ inch for the tongue of the astragal; *k j* is then made $\frac{3}{16}$ inch for rabbet, and *j m* is laid off $10\frac{1}{16}$ inches for glass. The $\frac{3}{16}$-inch rabbet is then again laid off from *m* to *l*, and *l o* is $1\frac{1}{2}$ inches for the meeting rail. The upper sash is then laid out in the same way—a rabbet of $\frac{3}{16}$ inch at *o n*, an opening for glass of $10\frac{1}{16}$ inches at *n r*, another $\frac{3}{16}$-inch rabbet *r p*, a $\frac{1}{2}$-inch tongue *r s*, a rabbet *t s*, a light *s v*, and a top rabbet *v u*; *u b* is then made 2 inches for the width of the top rail. The top and bottom rails are tenoned into the stiles, and *a g* and *b w* are laid out on the rod for a relish.

On the other side of the bar, from *c* to *d*, the divisions of the width are laid off in the same manner; *d t* and *c y* are each made 2 inches for the width of the stiles, *t s* and *y x* are then laid off for rabbet, and *t r* and *y g* are each made $\frac{1}{2}$ inch for the length of the tenon on the astragals; *s o* and *x g* are then made $8\frac{1}{16}$ inches for glass and the tongue *o g* is made $\frac{1}{2}$ inch.

56. At (*b*) is shown the side elevation, and at (*c*) the interior elevation of the two sashes in their relative positions. The upper and lower rails *a'* and *c'* are tenoned into a

mortise in each stile, as shown dotted at b', and are secured by means of $\frac{5}{16}$-inch pins w'. The tenons extend all the way through the stiles, and are seen on the side of the sash shown at b''. The astragals are also tenoned into a mortise sunk into each stile, but extending only $\frac{1}{2}$ inch into the wood, as shown at o'. The meeting rails are dovetailed to the stiles, as shown in the side elevation (b), at f'' d'', and the vertical astragals are mortised into the top and bottom rails, and are themselves mortised to receive the tenons of the cross-bars, as described below.

At (d) is shown the top edge of the lower rail, in the center of which is sunk the mortise a for the astragal; on the ends are seen the tenons c, which are to fit the mortises in the stiles. The molding on the inside of the rail is not mitered in the angle, but is coped over the stile molding, as shown at b and described hereafter.

57. At (e) is shown a section through the meeting rails, which illustrates the method of cutting the dovetails on the stiles to insure a satisfactory joint. The two meeting rails are first planed down to a section of $1\frac{1}{4}$ in. $\times 2\frac{1}{4}$ in., which would cause them to occupy the positions shown at $a\,b\,c\,d$ and $e\,f\,g\,h$, but they are afterwards beveled off on the line $j\,k$, as explained hereafter. The lower ends of the stiles of the upper sash, and the upper ends of the stiles of the lower sash, are then dovetailed as shown at $a\,d\,l\,m$ and $n\,o\,p\,q$ and at $s\,r\,e\,h$ and $v\,b\,t\,u$; the dovetail pins $l\,m\,n\,o$ and $u\,t\,r\,s$ are then cut on the meeting rails, and insure a joint which will be unlikely to work loose or shrink out of place after the sashes are hung. On the outside of the lower rail of the upper sash, a rabbet $w\,x\,m$ is cut to receive the glass; and on the under side of the upper rail of the lower sash, a groove $u\,y$ is plowed, to receive the upper edge of the glass in this lower sash.

The thickness of the stiles of the sash is only $1\frac{3}{4}$ inches from a' to b' or from c' to d', while, as stated before, the meeting rail extends nearly $\frac{1}{2}$ inch beyond this, or close to the edge of the parting strip. When the sashes are hung,

the edge of each meeting rail is planed off to the line *j k*; so that, when the sashes are closed in the position shown in the illustration, the beveled edges will act as a wedge, and by insuring a tight joint will tend to prevent the sashes from rattling.

58. At (*g*) is shown a plan of one of the horizontal bars mortised into a vertical one, thus dividing the sash into four parts. At *c* is shown the projection of the tenon which enters the mortise in the side of the sash, while the molding on the sash bar is cut out to cope over the molding on the stile as shown at *b*. The vertical bar is also similarly coped and mortised into the top and bottom rails of each sash, while at its center a mortise is cut entirely through the stuff to receive the tenon on the middle ends of the sash bar. This is more clearly shown at (*h*), where *a b c d* is a section through the vertical bar at the center of the joint. At *e f g h* is seen the portion which is cut through to receive the tenons of the sash bar, and at *e k* and *f l* are seen the mitered edges of the upper portion of the square section of the bar, which are so joined as to present a neat appearance, as well as to insure a perfect joint. The upper part of the bar *m o* is cut out to cope over the molded part of the bar at *b l*, and the tenon *o p q r* is inserted in the mortise *e f g h*, but extends only half way through it, or to the center line *t u*, leaving the other half of the mortise *e t u h* for the tenon on the other half of the horizontal bar.

The portion *r s* then butts against the rib at *v c*, and the whole is secured in place by the pressure of the stiles of the sash against the outer ends of the horizontal bars.

The mortising of the horizontal bars into the stiles is effected in precisely the same manner as into the vertical bar, the molded portion being coped and the solid central part let into the mortise.

59. On the side elevation (*b*) is seen at *a″* a round hole, $\frac{7}{8}$ inch in diameter and $\frac{3}{4}$ inch deep, bored in the sides of each sash just above the middle, to receive the knot of the sash cord which is to extend over the pulleys to the balance

weights in the weight box. A groove is cut $\frac{1}{2}$ inch wide and $\frac{1}{2}$ inch deep at c'' b'' for the cord to lie in, from the top of the sash to c''; and a hole $\frac{3}{8}$ inch in diameter, bored from c'' to the $\frac{7}{8}$-inch hole at a'', as shown by the dotted lines c'' a'', holds the cord in place, and prevents the knot from slipping out of the hole at a''.

At k'' l'' on this side elevation (*b*) is shown a portion of the parting bead in its position relative to the sashes. It will be readily seen that, as the meeting rails of the sashes extend beyond the interior and exterior faces of the upper and lower sashes respectively, the beveled portion of these rails must be notched out on the ends to fit around the parting bead.

60. When all the parts of a sash are made—stiles, rails, vertical and horizontal bars—the whole frame is drawn together with bench clamps, and then wedges dipped in glue are driven in on each side of each of the tenons b'. The mortises are made $\frac{1}{2}$ inch wider on the outside than on the inside of the stiles, to make room for the wedges, which are driven until the joint is closed tight. Holes $\frac{1}{4}$ inch in diameter are now bored through each mortise and tenon b' and each dovetail joint, and wood dowels dipped in glue are driven through the joint to secure it, as shown at w' in the elevation (*c*). When the clamps are removed from the sashes, the faces are smoothed and made ready for fitting into the frames.

61. Sashes should always receive one coat of paint before they are glazed, in order to prevent the wood from absorbing the oil from the putty with which the glass is fixed in place, and thereby rendering the putty brittle and inadhesive.

In glazing the sash, the rabbet is first prepared, by spreading a thin layer of putty along the glass bearing, to form a cushion, against which the panes of glass are first partly secured, by means of small triangular pieces of tin, called *glazing brads*, which are driven into the wood against the face of the glass. Putty is then spread in the rabbet to form a triangular fillet, and permanently hold the glass in

place. This putty extends to the outside of the rabbet and up the face of the glass to within $\frac{1}{16}$ inch of the daylight opening. The back putty which has squeezed out between the pane and the glass bearing is then scraped off flush with the daylight opening, and the sash is then set aside to await its second coat of paint.

If a pane of glass is curved slightly, it should be placed with its convex face to the weather, and, if warped so that its surface is not even, it should not be forced to a full bearing in the rabbet, but permitted to lie naturally in place, and any unevenness should be taken up in the bearings by back puttying—that is, the space between the glass and the bearing face of the rabbet is filled with a thin layer of putty, against which the uneven surface of the glass may rest.

62. To fit and hang the sash in the window frame, it is first necessary to remove the stop-bead and parting strip, and then fit the upper sash so that it slides easily between the pulley stiles. It is then secured in place by means of a couple of wood blocks nailed under it; the parting strip is replaced, and the lower sash is then similarly fitted. The lower rail of the sash is then planed off until the meeting rails rest snugly together, as required.

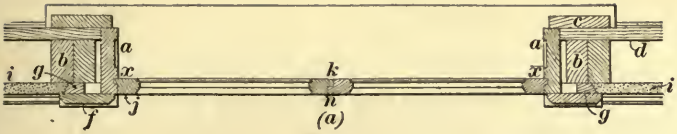
In providing weights for the sashes, the pair for the upper sash must be at least half a pound heavier than the weight of the sash, while for the lower sash the weights must be at least half a pound less than the weight of the sash. This half-pound excess in the upper weights and in the lower sash tends to keep the sashes close and tight against the window head and the sill.

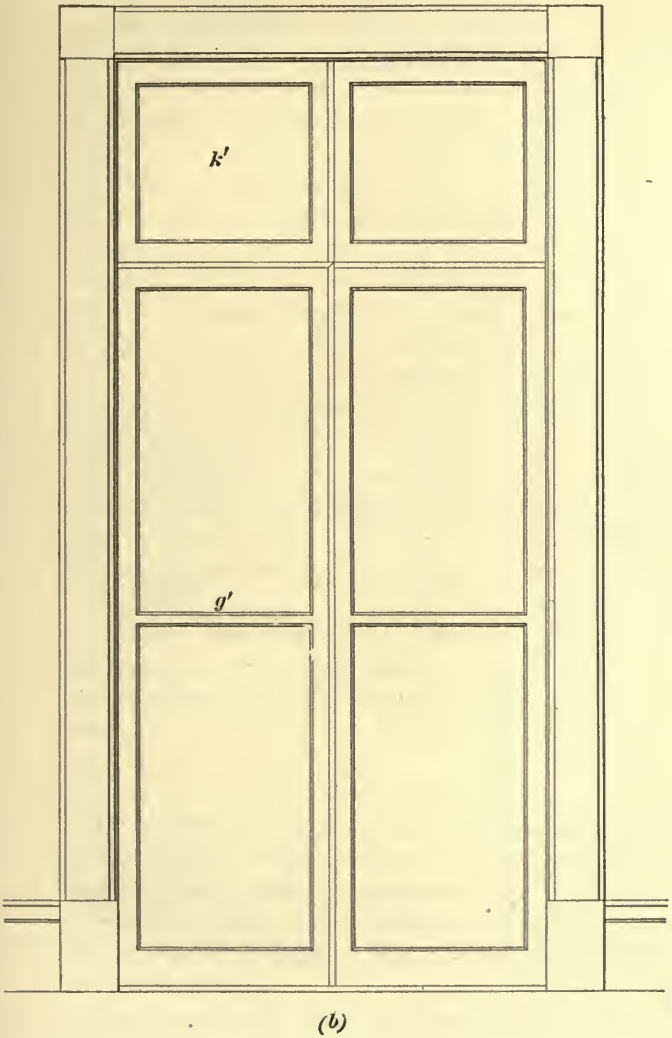
To hang the sash, the pockets must be opened by unscrewing and removing the covers. The sash cords are carried over the pulleys by means of a piece of light but strong string, which has been previously forced over the pulley and drawn down within the box with a lead weight, called a *mouse*, small enough to go over the pulley sheave, but heavy enough to carry the string. The sash cord is then made fast to the weight, and, with the top sash resting

equally on the sill, the weight is pulled up to the pulley, and the cord is cut off just long enough to permit a knot to be tied at the required point. By the use of metallic cord grips, knots on the ends of the sash cord are not required, but care must be taken to have the grip of a size to properly fit the cord. When both weights for the upper sash are thus attached, the sash is removed from the frame far enough to permit the cord to be pushed down through the groove and the hole seen at *g″ h″*, Fig. 28, and a knot is tied to prevent it from pulling out. When both weights and cords are thus attached, the sash is replaced in the frame, pushed up and down a few times to test its efficiency, and the lower sash is then hung in a similar manner. When the sashes are both hung, and are found to slide satisfactorily, the stop-bead is replaced and secured, and the pocket is closed and screwed up tight, to prevent the cover from catching on the lower sash.

63. Hinged sashes are, as previously mentioned, divided into two general classes; namely, those hinged at the sides, and those hinged at the top or bottom. The first named are usually hung in pairs, closing at the center with rabbeted meeting stiles in much the same way as a pair of folding doors, and are called "French casements," from the country of their origin.

Fig. 29 shows the plan (*a*), elevation (*b*), and section (*c*) of a French window, together with the general details of its construction. In the plan (*a*) are seen the double studs *b* forming the sides of the frame opening, over which the sheathing *d* is laid on the outside, and the grounds *g* and lath-and-plaster *i* on the inside. Extending through the opening, from the sheathing to the grounds, are the jambs *a*, the joints of which are covered on the outside by the casing, or blind-hanging stile, *c*, and on the inside by the trim *f*. Between these jambs, the two sashes are hinged and tongued into the jambs as shown at *x*, the corners of the stiles, however, being rounded as shown, to permit them to clear the groove in opening. The sashes are hung with





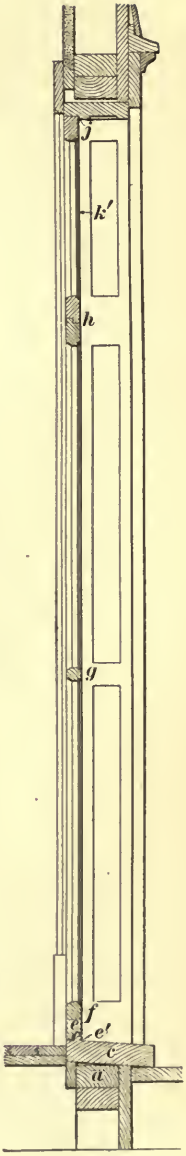


FIG. 29.

small hinges, and the meeting stiles are rabbeted in the same manner as are folding doors, as shown at *k n*, to enable them to make a tight joint when closed.

In the vertical section (*c*), taken through the center of one of these sashes, the rough sill of the stud opening is shown at *a*, while the window sill resting on the veranda floor is shown at *c*. This sill covers the bottom of the opening from the veranda floor to the inside of the lower sash rail *f*. This sash rail is grooved on its under side, as shown at *e*, and the sill is worked with a shoulder, the front of which is also grooved as shown at *e'*, while the top of it is beveled off at the same pitch as the sill. The groove in the front of the shoulder *e'* tends to prevent water from being blown into the crack during a rain storm, and the slanting sill and grooved lower rail permit the moisture to drip off the latter, and run to the outside of the opening.

At *g* is shown the section of the middle bar of the window, which is seen in the elevation at *g'*, and at *h* is shown the top rail of the hinged sash and lower rail of the fixed transom sash *k'* over it. The hinged sash is but 5 feet 6 inches in height, as this is sufficient to permit the window to be used as a means of ingress and egress, while the full opening is 7 feet high.

In the construction of the window head, the framing is precisely the same as at the sides, shown in the plan (*a*), except that the jamb *j* in the top of the window is not tongued as at *x* in the plan (*a*).

64. Windows in Curved Walls.—When the wall in which a window frame is to be built is not straight but curved, as would be the case in a circular tower or semicircular bay window, it is necessary to make a special form of frame laid out from a templet of the exact curve it is required to fit. And if, in addition to the wall being curved, the head of the window is semicircular or semielliptical, the problem is still further complicated by the necessary geometrical development of the details.

In Fig. 30 is shown the plan of a window opening and its

frame built in the curved wall of a tower. The pulley stiles a, a are set parallel to the axial line nf of the opening, so that the sash may be easily removed and replaced from the inside of the structure, which could not be done if the stiles were set on radial lines from the center of the curve.

The back lining is set parallel to the pulley stile to form a

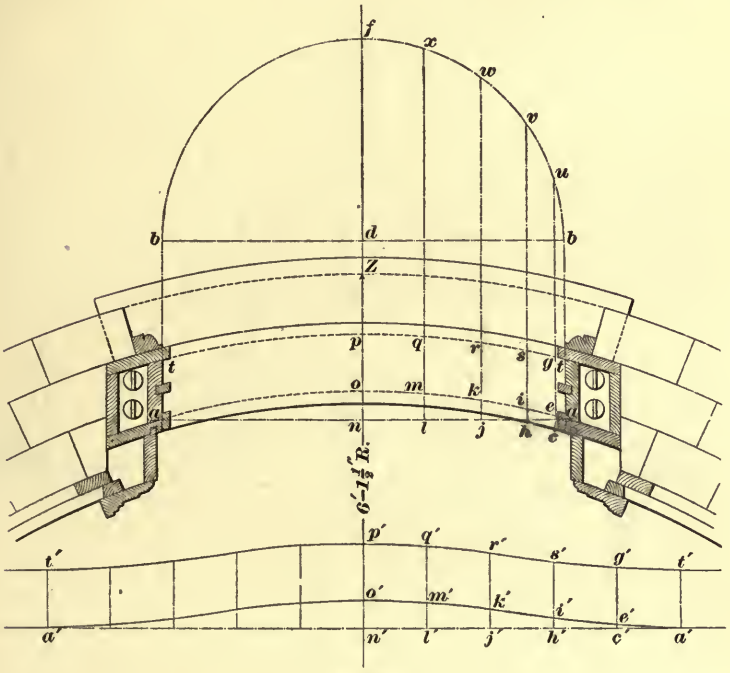


FIG. 30.

proper weight box, and the other details of construction are precisely similar to those described in connection with Fig. 23, except that, owing to the curvature of the sill and head, the details of the framing do not join at right angles, and the semicircular shape of the window head demands special construction.

65. To unfold or develop this semicircular window head, we proceed as follows: Draw a line $a\,a$ from the inside edges of the pulley stiles, and from each end of it erect the

perpendiculars *a b*, which will be equivalent to the continuation of the inside faces of the pulley stiles. Above the plan, draw the line *b b* parallel to *a a*, and with the point where this line intersects the axial line *n f* at *d* as a center,

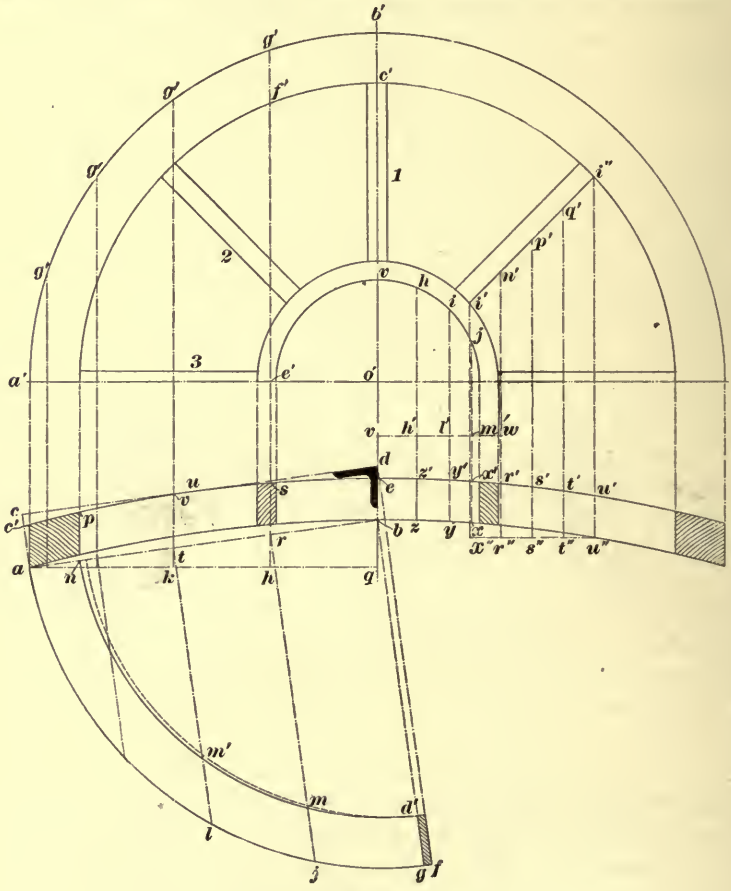


FIG. 31.

and *d b* as a radius, draw the semicircle *b f b*, which will be the elevation of the inside line of the window head. Now divide one-half of this semicircle *b f b* into any number of equal parts, by points *u*, *v*, *w*, *x*, etc., and from these points let fall perpendiculars to *a a*, as shown at *x l*, *w j*, *v h*, etc.

Somewhere below the plan, the line $a' a'$ is then drawn, parallel to $a\,a$, from the center n' of which is laid off in each direction the lengths $n' l'$, $l' j'$, $j' h'$, etc. each equal to the length of the curved lines $f x$, $x w$, $w v$, etc., and, from the points so established, perpendiculars to $a' a'$, as $n' p'$, $l' q'$, $j' r'$, $h' s'$, etc., are erected. On these perpendiculars are laid off $n' o'$ and $n' p'$ equal respectively to $n\,o$ and $n\,p$, $l' m'$ and $l' q'$ equal to $l\,m$ and $l\,q$, $j' k'$ and $j' r'$ equal to $j\,k$ and $j\,r$, etc. These measurements are taken from the plan, where the perpendiculars from the subdivisions of the semicircle $b\,f\,b$ intersect the curved lines $a\,o\,a$ and $t\,p\,t$, shown in the plan of the sill. Curved lines drawn through the points p', q', r', s', g', t' and o', m', k', i', e', a' will describe the contour of the flat piece required to conform to the shape of the window head when bent around a semicircular form similar to $b\,f\,b$. The method of bending this semicircular head is described in subsequent articles.

66. The construction of a sash whose plan is the segment of a circle, and whose head is a semicircle, is shown in Fig. 31. It is designed to fit the curved window frame just described.

The most satisfactory way of constructing this sash head is to form it of two pieces, each piece being a quarter circle; and, as each of these quarter circles will have a compound curve, it will be necessary to prepare a face mold from which to mark out the curve. To do this, first draw the line $a\,b$, Fig. 31, on the concave side of the sash, from the outside edge to the center, and on the convex side draw the lines $c\,d$ parallel to $a\,b$ and tangent to the sash at u; also draw $a\,c$ perpendicular to $a\,b$. The rectangle $a\,b\,d\,c$ then represents the thickness and width of plank required to get out each piece of the top rail. Now divide the curved outside line of the elevation of one-half the window head $a' b'$ into any number of equal parts by points g', g', and from each of these points draw lines parallel to the center line $b' e$, intersecting $a\,b$ at r, t, etc.; and from these points of intersection draw the lines $b\,g$, $r\,j$, $t\,l$, etc., and the line $d\,f$, all perpendicular

to *a b*. Lay off on these lines the distances *b d'*, *b g*, *r m*, *r j*, *t m'*, *t l*, etc., equal respectively to *o'c'*, *o'b'*, *e'f'*, *e'g'*, etc., and through the points thus established draw the curves *a l g* and *n m' d'*. Then the curved form *a l g d' m' n* will be the face mold which must be applied to and scribed on the stock, from which the half-sash head is to be sawed. The shaded portion at *g f*, shows the waste or surplus, which must be removed in order to permit the two quadrants to meet in a proper butt joint at *b e*. This surplus is removed on the bevel shown at *d*, which is the angle *c d q*, formed by the intersection of the tangent line *c d* with the prolongation of the perpendicular center line *b' b*.

The dotted curved line on the concave side of the face mold shows the amount of extra width required, owing to the fact that the head-piece is sawed squarely through the wood. The plank from which the sash head is to be cut, is first planed on its inside edge to conform with the bevel shown at *d*. The face mold is then set to the edge of this bevel on both sides of the plank and marked, and the surplus wood is then cut away to the lines as marked. The convex and concave edges of the circular head on the plan lines *a c' e b* and *n p e b* will then have the proper shape and angle.

67. Two patterns must now be made which may be applied to the finished convex and concave edges of the circular top rail, in order to mark the convex face line of the sash. To prepare these patterns, first draw a line *a b*, Fig. 32, on it lay off the distances *a d*, *d g*, etc. equal to the divi-

FIG. 32.

sions *a' g'*, *g' g'*, etc. on the convex side of the sash head *a' b'* in Fig. 31, and from these points erect the perpendiculars *a c*, *d f*, *g i*, etc. equal respectively to *q e*, *h s*, *k v*, etc. of Fig. 31. Then through the points *c*, *f*, *i*, etc., draw a curved

line, which will be the line required on the convex face of the sash head. Before applying this pattern to the sash head, it will be necessary to trace another curve *l e h b*, which will act as a guide in placing the pattern in position for scribing. To do this, *a l*, *d e*, *g h*, etc. are laid off equal to *q b*, *h r*, *k t*, etc. of Fig. 31, and the curve *b h e l* is then drawn through the points so located. The pattern *b h l c i k* is then cut out and bent around the convex edge of the rough-sawed window head *a b d c*, Fig. 31, in such a position that *b h e l* corresponds with the inside line of the plank, as *a t r b* of Fig. 31. The outside curve *k i f c* is then scribed on the sash head, and will conform to the curve required.

The other pattern is required to trace this same curve on the concave side of the sash head. On the line *w k*, Fig. 33,

FIG. 33.

are laid off the distances *k o*, *o r*, etc. equal to *c' f*, etc., on the concave side of the window head in Fig. 31, and, on the perpendicular lines raised from these points, the distances *k m*, *k n*, *o p*, *o q*, *r s*, *r t*, etc. are laid off equal respectively to *q b*, *q c*, *h r*, *h s*, *k t*, *k v*, etc. of Fig. 31. The curves traced through the points *n q t x* and *m p s w* will then form the pattern for the concave side of the window frame, which must be applied in the same manner as the pattern described in Fig. 32 is applied to the outside, the line *m p s w* being made to conform to the straight line *n b* of the concave side of the sash shown in Fig. 31.

These patterns may be cut out of strawboard, or thin sheet zinc, so that they may be readily bent to the curved edges of the top rail. The pattern shown in Fig. 32 is bent around the outside of the top rail, pressed closely and temporarily tacked into place, keeping *l c* to the joint, and the line *l e h b* to the straight face of the plank marked *a b* on the plan in Fig. 31, the convex face line *c f i k* being then marked on the sash head. The pattern shown in Fig. 33 is applied in

the same manner to the under or concave side of the sash head, keeping the line *m n* to the joint and scribing the curve *n t x* on the outside or front edge of the sash. The surplus, or overwood, is then planed off to the convex lines so marked on the sash head, always working the plane in a direction parallel to the joint line *g d'*, Fig. 31. When this is done and the convex face of the frame is finished, the scratch gauge is set to the thickness of the sash, and the concave or inner face of the sash is gauged from the outside. The overwood is then removed as before, moving the plane in the same direction and finishing carefully to the scribed lines.

The two quadrants, each representing one-half the sash head, are now doweled together as shown at *b* and *b'* in Fig. 34, and secured with a hand-rail bolt in the center, as shown at *a* and *a'*, to bring them into close contact, while a dowel in each of the two opposite corners at *b'* serves to keep the pieces in proper alinement. The pieces are then glued together, and the moldings are worked.

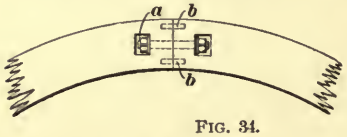


FIG. 34.

68. The arch bar may be sawed out of a single piece of plank in the same manner as each half of the window head, or it may be bent in one or more thicknesses of wood, laid out from a pattern drawn as follows: The concave side of the arch bar, Fig. 31, is divided into any number of equal parts, as *h*, *i*, *j*, etc., from which perpendicular lines are dropped to the plan, intersecting it at *z'*, *z*; *y'*, *y*; *x'*, *x*, etc. At any convenient point above the plan a horizontal line *v w* is drawn, intersecting the perpendiculars at *h' l' m'*, etc. Now, on a line *a b*, Fig. 35, the points *v*, *h*, *i*, *j* are laid off on each side of the perpendicular center line *c v* at a distance from each other equal to *v h*, *h i*, *i j*, etc., Fig. 31. From these points, the lines *j x*, *i y*, *h z*, etc. are drawn perpendicular to *a b*,

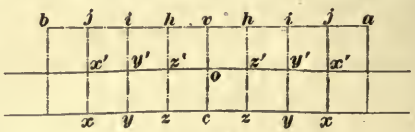


FIG. 35.

and the distances jx', jx, iy', iy, hz', hz, etc. are laid off on these perpendiculars equal respectively to the distances $m'x'$, $m'x$, $l'y'$, $l'y$, $h'z'$, $h'z$, etc., in Fig. 31. Through the points o, z', y', x', etc. and c, z, y, x, etc., curved lines are drawn giving the proper shape for the front and back edge, respectively, of a plank which is to be bent over a prepared center to form the semicircular arch bar of the sash.

69. The radial bars in this sash head have different curves, according to their position. No. 1 is straight, as it is in the center of the convex surface, and is parallel with the axis of the cylinder, of which the curved front of this window forms a part. No. 3 is curved to the arc of a circle whose radius is the same as the plan of the window, because it is parallel to the base of the cylinder of which the curved front forms a part. No. 2, however, being parallel to neither the axis nor the base, takes a diagonal direction around the surface of the cylinder and, therefore, is curved to the form of a portion of an ellipse.

To lay out the face mold, from which this elliptical curve may be marked on the plank for the radial bar, proceed as follows:

Divide the length of the radial bar in Fig. 31 into any number of equal parts by the points i', n', p', q', etc., and drop from each division a perpendicular line intersecting the curved plan lines at $r'r''$, $s's''$, etc. Then, on a horizontal line, as $v'u'$, Fig. 36, lay off the distances $v'n$, np, pq, etc., equal to $i'n'$, $n'p'$, $p'q'$, etc., in Fig. 31, and lay off, on the perpendiculars erected at these points, the distances $v'h$, nr, ps, etc., equal to $x'x''$, $r''r'$, $s''s'$, in Fig. 31, and through the points h, r, s, t, u, draw a curve which will give the outside line of the face mold required. The inside line of the face mold is then found by drawing a curve through the points h', r', s', etc., which are located so as to make the distances hh', rr', ss', etc. equal to the thickness of the sash on the lines $r'r''$, $s's''$, $t't''$, etc. of Fig. 31.

FIG. 36.

SPLAYED WORK.

70. **Splayed work** in joinery is the term applied to cases in which some of the surfaces slope or slant away from, or towards, other surfaces, such as the sides of a pyramid. Such work is frequently encountered in the jambs, sills, or sides of windows or doors, or in the sides of any piece of work placed in an oblique direction to a horizontal or vertical plane.

71. Fig. 37 shows a box, the sides of which *splay* out from the bottom *a b c*, to the top *d e f*. To find the angles required in the construction of a square box, or hopper such as is shown

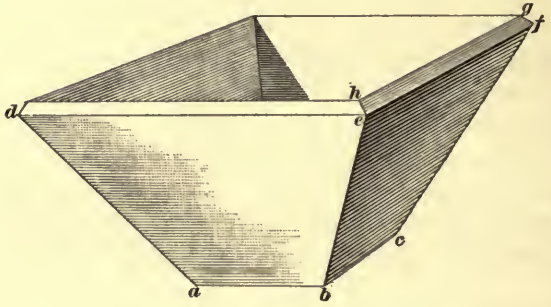


FIG. 37.

in Fig. 37, all four of whose sides splay equally, proceed as follows: Let *b c*, Fig. 38, be the required splay and position of the sides of a box in relation to the horizontal plane *d s*, and suppose *a b* to be the thickness of the material from which the box is to be made; then *a b c t* is the end section of the material. Now, from *c* at right angles to *d s*, draw *c j* equal to *c b*; through *j* parallel to *d s* draw *p h*, and from *b* draw *b h* at right angles to *p h*; connect *h c*; then the angle *j h c* is the inside face bevel for the sides, and *p h c s* is the size and shape of the inside faces of the box.

72. To find the bevel for a butt joint on the square edge from *a*, Fig. 38, draw *a f* parallel to *h j*; from *f*, draw *f g* at right angles to *h j*; make *i g* equal to the

thickness *b a*; connect *h g*; then the angle *j h g* gives the bevel required.

To find the bevel for a miter joint on the square edge—as *g h e* in Fig. 37—make *c e* equal to *d c*; parallel to *c h* draw *e o*; connect *o g*, then the angle *j o g* is the miter bevel sought; *o g* apparently coincides with *e o* prolonged, but it does not actually do so.

To find the angle between the two inside faces in a direction at right angles to the face joint *p s*, draw *k l* at any point

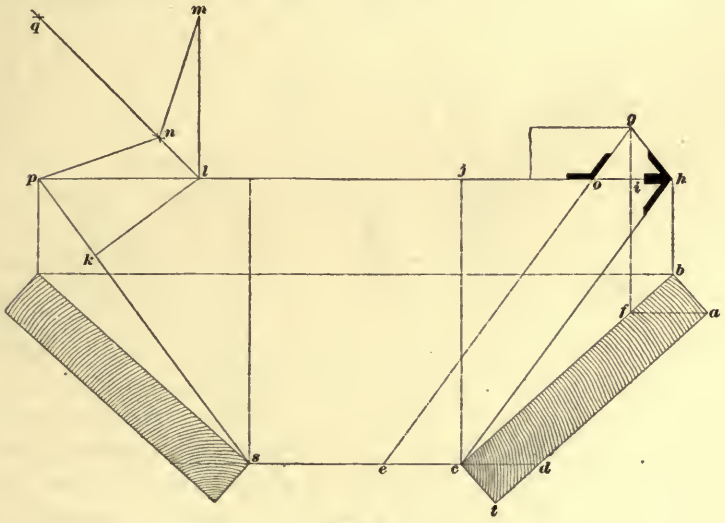


FIG. 38.

along the line *p s*, and at right angles to it; at right angles to *p l*, draw a line through *l*; make *l m* equal to *l p*; with *m* and *p* as centers, describe the intersecting arcs at *q*; connect *q l*; with *l k* as radius, and on *m* and *p* as centers, describe intersecting arcs at *n*; connect *n* to *m* and to *p*; then *m n p* is the angle sought. Also, the angle *p n l* is the angle of miter through the thickness holding the stock of the bevel in the direction *k l*. A block beveled to the angle *m n p* will fit the angle formed by the connecting faces of the box. If either edge of the box is beveled to *c d* or *f a*, then a square line on either of these edges from the face *c b* will be a

butt-joint line through the thickness. An angle of 45° applied from the face on either beveled edge *c d* or *f a* will also be a correct miter through the thickness.

In dovetailing a box like this, instead of squaring across the ends for mortises, use the angle *c f a* or *d a f*, and, instead of squaring from the ends for the pins, use the angle *c h j*.

73. To find the angles required for the construction of a hexagonal box such as shown in Fig. 39: Let the hexagon (*a*) be the plan of the box; then draw *y w* at right angles to *s c*, one of the sides of the hexagon, and let *y j* be the distance over which the splay extends horizontally. Through *j*, parallel to *s c*, draw *u o*, and lay off *j v* equal to the height of the box; draw *v y*, and draw *v z* at right angles to it, and equal to the thickness of the sides; parallel to *y v* draw *z k*; draw *y k* perpendicular to *v y*; then *y v z k* is a cross-section of the stuff from which the box is to be made.

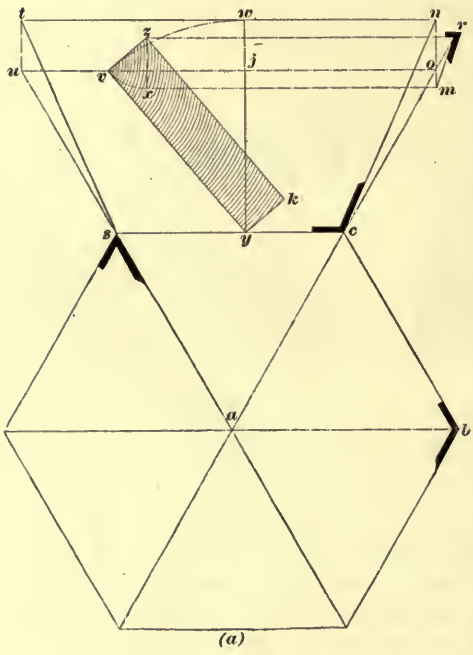


FIG. 39.

To find the face-joint angle, make *y w* equal to *y v*; through *w*, parallel to *s c*, draw *t n*; prolong the miter line *a c* towards *r* indefinitely; through *o* the intersection of *a c* prolonged and *u o*, draw a line parallel to *y w*, intersecting *t w n* in *n*, and connect *n c*; the face joint is then indicated by the bevel at *c*.

To find the angle of the butt joint to apply on the square

edge $v\,z$: From z draw $z\,x$ parallel to $y\,w$, and equal to $z\,v$; from x, parallel to $s\,c$, draw $x\,m$; prolong $n\,o$ to m, and parallel to $s\,c$, draw $z\,r$, and connect $r\,m$; the angle required is as indicated by the bevel r. If either edge is beveled on the line $y\,w$ or parallel to it, the angle of the butt joint to apply to that edge must be taken at b, while for the miter joint the angle at s must be taken.

74. To find the miter for the joint of an inclined sill over an obtuse angle: Let $l\,z\,t$, in Fig. 40, be the angle over which

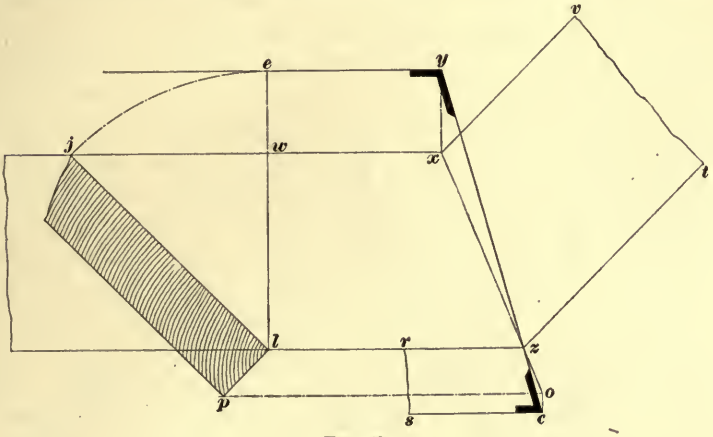


FIG. 40.

the sill is to incline, and let $j\,x$ and $x\,v$ be lines parallel to, and equidistant from, $l\,z$ and $z\,t$; then will $z\,x$ be the plan of the miter line of the sill. Now draw $l\,e$ at right angles to $l\,z$, and let $w\,j$ be the height, $j\,l$ the pitch, and $l\,p$ the thickness of the sill. To find the miter angle down the face of the sill, make $l\,e$ equal to $l\,j$, and parallel to $z\,l$, draw $e\,y$ indefinitely; then parallel to $l\,e$ draw $x\,y$, cutting $e\,y$ in y, and connect y and z. The bevel at y then indicates the miter angle across the face of the sill.

To find the miter angle on the square edge $l\,p$, prolong the plan miter $x\,z$ towards o indefinitely, and parallel to $l\,z$ draw $p\,o$. Draw $o\,c$ at right angles to $l\,z$, and prolong it indefinitely; make $r\,s$ equal to $l\,p$, draw $s\,c$ parallel to $l\,z$, and

connect $c\,z$; the bevel at c will be the angle sought. If the bottom of the sill is horizontal, then $l\,z\,x$ will be the angle of miter on that face.

75. To find the bevel for mitering the angles of a square or an octagonal pyramid: Let $a\,b\,d\,f$, Fig. 41, be the base of a square pyramid, and $h\,j\,k\,c\,l\,m\,n\,g$, the base of an octagonal pyramid. Make $s\,e$ the height of the pyramid, and draw $f\,e$, $d\,e$, $n\,e$, and $m\,e$; $d\,e\,f$ will then be a side of the rectangular pyramid, and $m\,e\,n$ a side of the octagonal one. Draw $f\,b$ as the plan miter of the square base, and $g\,c$ as the plan miter of the octagonal base; then, with d as a center, describe the tangent arc $j\,i$. Connect $i\,a$, and the bevel at v will indicate the angle sought for the miter of the square pyramid, while the bevel at t will indicate the miter for the sides of the octagonal pyramid. In mitering the sides of either pyramid, the bevel must be held with its stock at right angles to the edge, as shown at n.

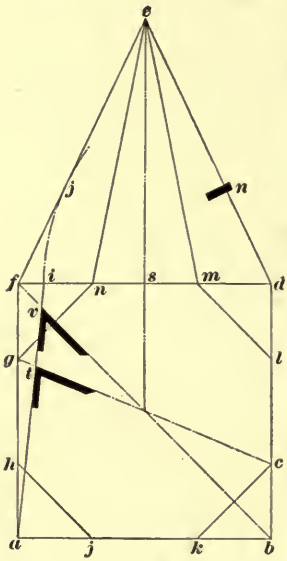


FIG. 41.

76. **Window** or **door openings** in straight walls with splayed jambs and circular splayed soffits present problems requiring an accurate knowledge of the treatment of splayed work, to secure the proper bevels and joints. To unfold the length and shape of such a window soffit on the plan of the window shown in Fig. 42, let $a\,a'$, $b'\,b$ be the opening, with splayed jambs $a\,b$ and $a'\,b'$ and circular soffit equally splayed. Continue the splay lines of each jamb $a\,b$ and $a'\,b'$ until they intersect at d; draw the elevation of each side of the opening as at $a\,c\,a'$ and $b\,f\,b'$; divide the semicircle $a\,c\,a'$ into any number of equal parts, say six; with d as a center, describe

the arcs $a\,g$, $e\,e'$, $i\,i'$, and $b\,h$, all of indefinite length; on the arc $a\,g$, lay off the six parts taken from $a\,c\,a'$ and connect g to d; then $a\,b$ to $e'\,h$ is the length and shape of the soffit

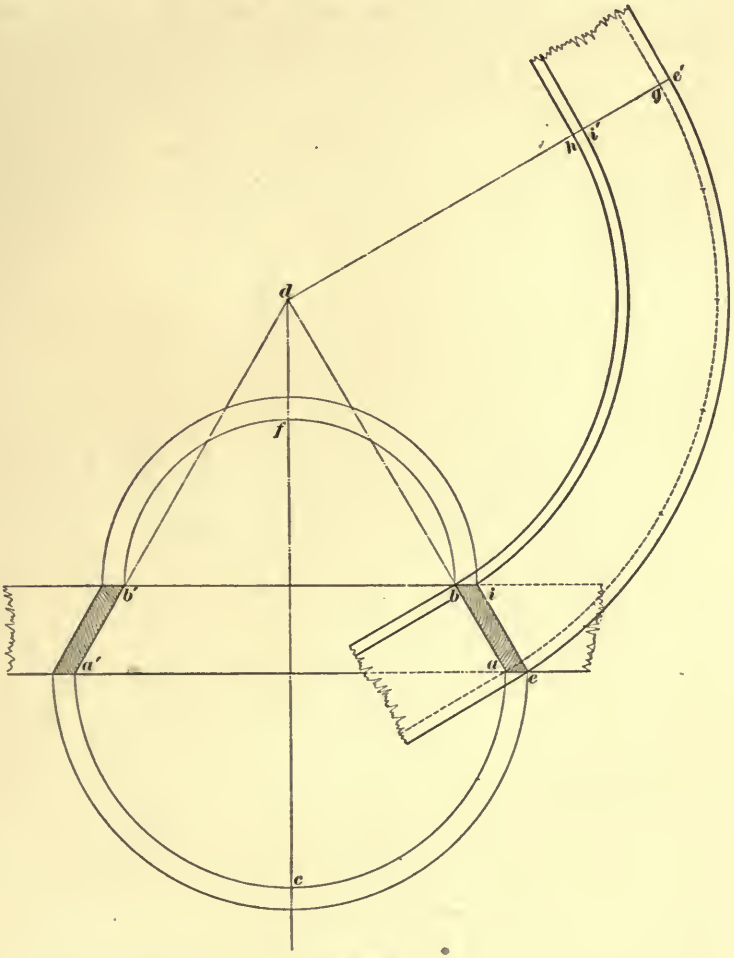


FIG. 42.

to be bent over a center after being treated by some one of the several methods hereafter explained. After the soffit is bent, the edges must be beveled as shown. Whether bent by means of keyed grooves—saw kerfed or built up and

backed with staves—the grooves or staves must radiate from the center *d*.

77. Window or door openings in a straight wall with splayed jambs and pointed soffits next demand attention. To unfold the length and shape of the soffit on the plan shown in Fig. 43, let $r r'$ and $p p'$ be the plan of the opening; let $p r$ be

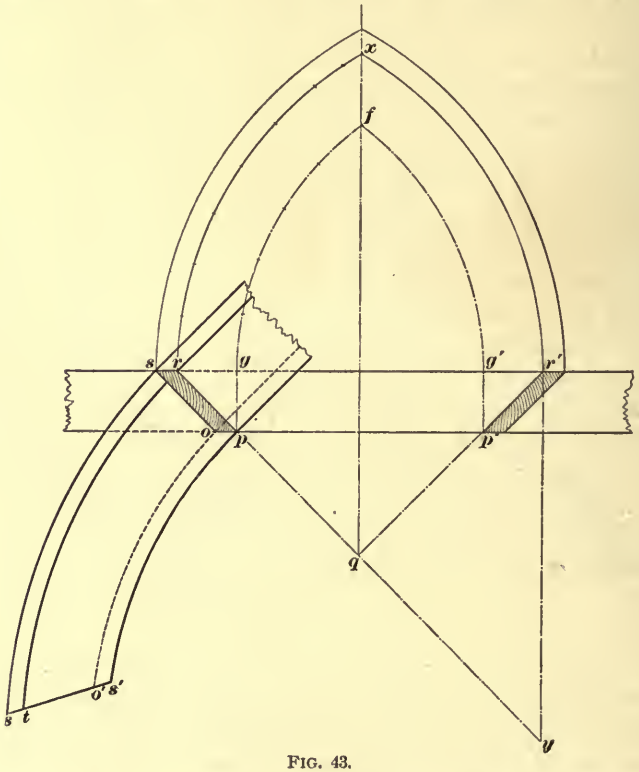


FIG. 43.

the splay of the jambs; and let $q x$ be a center line of the plan. Parallel to $q f$ draw $p g$ and $p' g'$; with r' as a center, describe the arcs $g f$ and $r x$ and divide them into any number of equal parts—as $g f$ into five parts, and $r x$ into seven. Draw $r' y$ parallel to $x q$, and prolong $r p$ to y. On y as a center, describe the arcs $s s$, $r t$, $o o'$, and $p s'$; on the curve from p to s', set off the five divisions of the line $g f$; on $r t$, set off

the seven divisions of the line $r\,x$, and connect $s'\,t$; then $p\,s'\,t\,r$ is one side of the soffit, which will have to be bent over a suitable center by some of the methods hereafter explained. From $p\,r$ the straight jamb will have to be spliced as the height may require.

78. The plan of a window or door opening in a circular wall, the jambs of which radiate to the center from which the circular wall is described, and the soffit of which is circular, is shown in Fig. 44. To unfold the shape and length of the soffit, let h be the center from which the circular wall

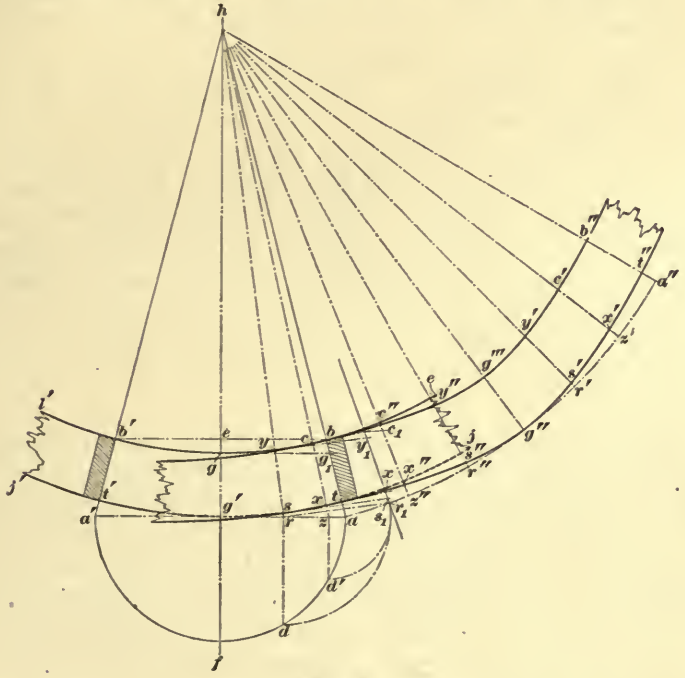


FIG. 44.

$j'\,g'\,t\,b\,g\,l'$ is described, and $h\,f$ the center line of opening; draw $b'\,b$ at right angles to $h\,f$, and equal to the required opening at the concave face of wall; from h, through b and b', draw $h\,a$ and $h\,a'$; draw $a\,a'$ at right angles to $g'\,h$, and tangent to the outer curve of the wall at g'; $t\,b$ and $t'\,b'$ are then

the faces of the jambs. From g' as a center, describe the semicircle $a' f a$; divide the quarter circle $f a$ into three or more equal parts, as at d and d'. From these points draw perpendiculars to $a' a$, as $d r$ and $d' z$, and draw $r h$ and $z h$. With h as a center, describe the arc $a a''$ of indefinite length; on it, twice set off the number of divisions of $a f$, as $a z''$, $z'' r''$, etc.; from these points, draw lines to h. Next project g to g_1, and g' to a; then $g_1 a$ is the true length of $g g'$. On $h g''$, which is $h g'$ in the development, lay off, from g'', $g'' g'''$ equal to $g_1 a$. Again, from r, draw $r r_1$ perpendicular to $h r$, and equal in length to $r d$. Draw $h r_1$; also draw $s s_1$ and $y y_1$ perpendicular to $h r$; then $y_1 s_1$ is the true length of $y s$. Mark it on the corresponding lines $h r''$ and $h r'$, by making $r'' s''$ and $r' s'$ equal to $r_1 s_1$; and $s'' y''$ and $s' y'$ equal to $s_1 y_1$. Similarly, find the true length of $c x$, and lay it off on $h z'$ and $h z''$. As $a t$ and $t b$ are shown in their true length on the plan, $a'' t''$ and $t'' b''$ are laid off on $h a''$ equal to the corresponding lengths on $h a$. Through all the points thus found, draw the outlines, and the figure $t b g''' b'' t'' g''$ will be the required development of the soffit. From $t b$ and $t'' b''$ the straight jambs will be spliced to the length required, a splicing portion to be left on at both sides. This soffit will also have to be bent over a suitable center in one of the ways hereafter described.

79. The plan of a window or door opening in a circular wall where the jambs and circular soffit splay equally, is shown in Fig. 45. Let A be the circular wall, and $a b$ and $a' b'$ the splayed jambs of the opening. Draw $a' a$ equal to the width of the opening on the concave side of the wall, and $b' b$ equal to the width of the opening on the convex side of the wall. Continue the sides of the jambs $a b$ and $a' b'$ till they intersect at e. Draw $e f$ at right angles to $a' a$; with r as a center, describe the semicircle $a' f a$. Divide the quarter circle $a f$ into three or more equal parts, as at k and k'; from these points draw $k n$ and $k' p$, perpendicular to $a' a$; also, draw $e p$ and $e n$. With e as a center and $e a$ as radius, draw the arc $a a''$ of indefinite length, and lay off from a on it the distances $a n''$, $n'' p''$, etc., equal to $a k$, $k k'$, etc., the

number of divisions being twice those laid off on af; draw lines from e to n'', p'', etc. To find any developed length, uqp, for example, draw pp_1 perpendicular to ep, and equal in length to pk'; also draw ep_1. Draw uu_1 and qq_1 parallel to pp_1; then p_1q_1 and q_1u_1 are the true lengths

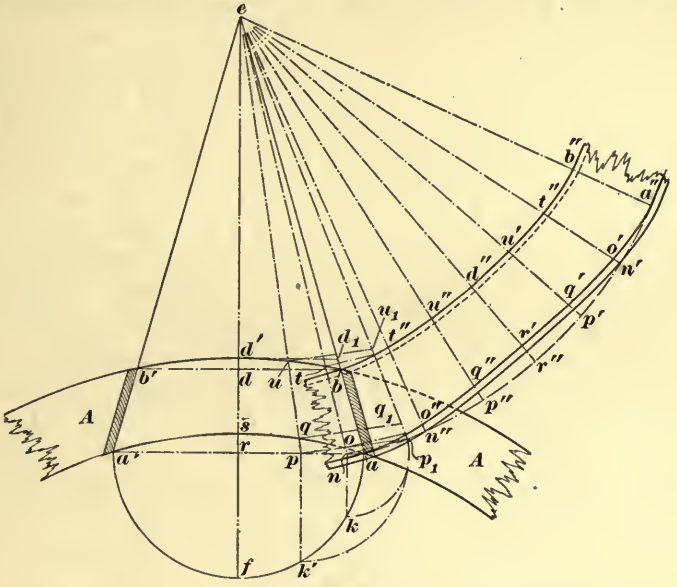


FIG. 45.

of pq and qu, and, laid off as shown on the proper lines, corresponding to ep, as ep' and ep'', will give points on the development of the soffit. All other points being found in the same manner, the complete development is $b\,d''\,b''\,a''\,r'\,a$. The outer full line and the dotted line represent the beveled edges of the soffit.

80. The plan of a window or door opening in a straight wall with splayed jambs, and a semicircular soffit on one side of the wall, and a semielliptical one on the other side, so arranged as to preserve the crown of the soffit level, are shown in Fig. 46. Let A be the wall, and $a\,a'$, $o\,o'$ the opening and splay of the jambs; continue the splayed-face line of the jambs $a'\,o'$ and $a\,o$ to f; through the center of the

opening, draw the center line fj; from k as center, and with a radius ko', draw the semicircle $o'uo$, which will be the interior elevation of the window head, and divide it into any number of equal parts—in this case six; through each of these parts, as r, t, etc., let fall a perpendicular to $o'o$, as rc, td, etc. From f, through c and d, draw fz' and fv, and

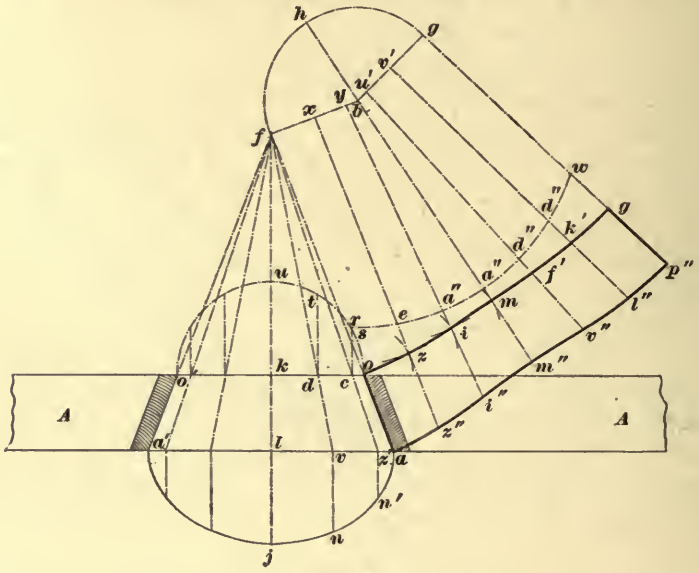


FIG. 46.

repeat the construction on the other side of the center; at right angles to aa' draw $z'n'$, vn, lj, etc.; make $z'n'$, vn, lj, equal to cr, dt, ku, etc., respectively, and through these points trace the semiellipse $an'nja'$, which will be the outline of the exterior of the opening. To find the length and shape of the soffit, draw fb at right angles to fa; make fx, fy, and fb equal to cr, dt, and ku, respectively; with fc as a radius, and with x as a center, describe an arc at z; then, with os as a radius, and with o as center, describe another arc at z intersecting the first one. Through z draw the line xzz'' indefinitely; with fd as a radius, and y as center, describe an arc, and with st as a radius, and z as center, describe a second arc intersecting the first at i; from

y draw through i the indefinite line $y\,i\,i''$. Next, with $f\,k$ as a radius, and b as a center, describe an arc, and with $t\,u$ as a radius, and i as a center, describe a second arc intersecting the first at m; through m then draw the line $b\,m\,m''$ indefinitely. With b as a center and $b\,f$ as a radius, describe an arc $f\,h\,g$. Prolong $m\,b$ to h; make the arc $h\,g$ equal to the arc $h\,f$ and connect $b\,g$; make $b\,u'\,v'$ equal to $b\,y\,x$. With b as a center, with any convenient radius, describe a measuring arc $r\,w$; from a'', where the line $h\,m''$ intersects this arc, lay off the spaces $a''\,d''$, $d''\,d''$, and $d''\,w$ equal to $a''\,a''$, $a''\,e$, and $e\,r$ on the opposite side; through w draw $g\,w\,p''$, and then through these points draw $v'\,l''$, $u'\,v''$, etc. Make $z\,z''$ equal to $c\,z'$, $i\,i''$ equal to $d\,v$, and $m\,m''$ equal to $k\,l$, etc.; make $w\,g$ and $w\,p''$ equal respectively to $r\,o$ and $r\,a$, $d''\,k'$ and $d''\,l''$ equal respectively to $e\,z$ and $e\,z''$, and $d''\,f'$ and $d''\,v''$ equal respectively to $a''\,i$ and $a''\,i''$; a curve through $o\,z\,i\,m\,f'\,k'\,g$ is the interior edge of the soffit; and one through $a\,z''\,i''\,m''\,v''\,l''\,p''$ is the exterior edge. Sufficient overwood

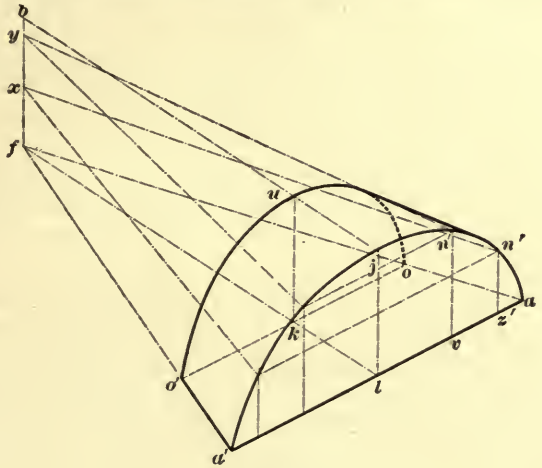


FIG. 47.

must be allowed beyond $g\,p''$ and $o\,a$ to bevel the edges of the soffit to attach to the straight jambs, $p''\,g$ and $a\,o$, which are spliced on as required. The soffit must be bent over a suitable center.

To insure a better understanding of this work, a perspective drawing of the conelike solid, the surface of which corresponds to the contour of the inside of this arched opening, is shown in Fig. 47. At the interior, the opening is circular, as shown at $o'\,u\,o$, and, the top $u\,j$ being level, the height $j\,l$ on the exterior is the same as the height $k\,u$ on the interior; but the sides of the opening splay towards the outside, and the width on the exterior $a'\,a$ is greater than the width on the inside $o'\,o$, so that the exterior elevation of the opening $a'\,j\,a$ is elliptical. The other letters in Fig. 47 refer to the same points as similar letters in Fig. 46.

81. A plan of a window or door opening in a concave circular wall, with the jambs splayed, the soffit a semicircle on one side of the wall, and the other side a semiellipse, the crown of the soffit being level, is shown in Fig. 48. Let B be the circular wall, and $b\,b'$, $d\,d'$ the opening and splay of the jambs; continue the splayed face of jambs $b'\,d'$ and $b\,d$ to g; from g through the center of opening draw the center line $g\,y$ indefinitely; from f, the intersection of this center line with the line $d\,d'$, describe the semicircle $d'\,p\,d$, and divide it into any number of equal parts, through each of which, as i, n, etc., let fall perpendiculars, $i\,c$, $n\,a'$, etc., to $d'\,d$; from g draw lines through c and a' to e' and l; perpendicular to $b'\,b$ draw $e'\,m$ and $l\,m'$ equal respectively to $c\,i$ and $a'\,n$; make $q\,y$ equal to $f\,p$, and then trace the exterior semiellipse $b\,m\,m'\,y\,b'$.

To find the length and shape of soffit, draw $g\,s$ at right angles to $b\,g$; make $g\,k$, $g\,z$, etc. equal to $c\,i$, $a'\,n$, etc., and with s as a center, describe the arc $g\,w\,x$ of indefinite length. With $g\,o$ as a radius, and k as a center, describe an arc, and with $d\,i$ as a radius, and d as a center, describe a second arc cutting the first at c'; through c' draw $k\,s''$. Next with $g\,a$ as a radius, and z as a center, describe an arc, and with $i\,n$ as a radius, and c' as a center, describe a second arc intersecting the first at n'; with $g\,h$ as a radius, and s as a center, describe an arc at v; with $n\,p$ as a radius, and n' as a center, describe an intersecting arc at v, and through s and v draw $s\,v'$

indefinitely. Make $c' s''$, $n' t''$ and $v v'$ equal to $o e$, $a l'$, and $h j$, etc., respectively. Make $w x$ equal to $w g$; connect $s x$; make $s o'' x'$ equal to $s z k$; from s as a center, with any convenient radius, describe a measuring arc $r p' u$, make $p' u$ equal to $p' r$; through u draw $x b''$. Lay off $u j'$, $u b''$, $r' z'$,

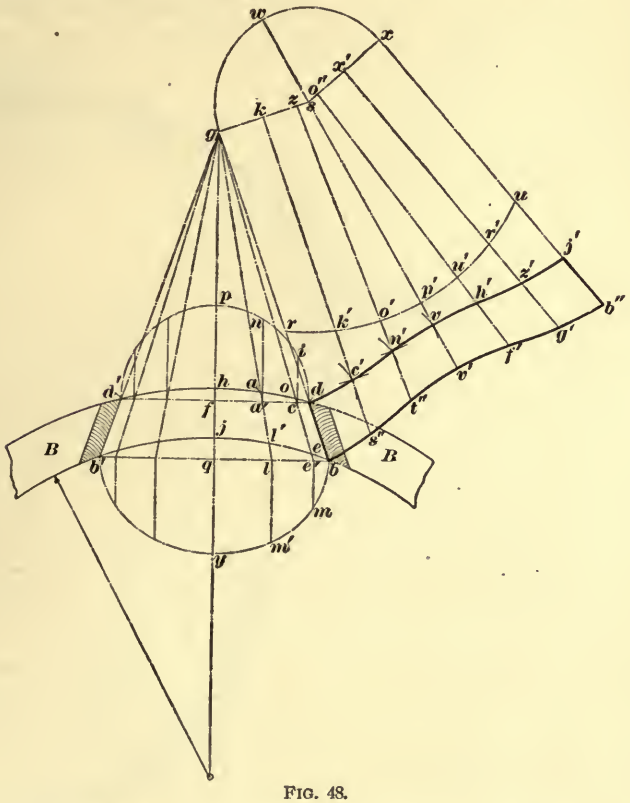


FIG. 48.

$r' g'$, $u' h'$, and $u' f'$ equal respectively to $r d$, $r b$, $k' c'$, $k' s''$, $o' n'$, and $o' t''$; through the points d, c', n', v, h', z', j' trace a curve, which will be the convex edge of the soffit; and through the points b, s'', t'', v', f', g', b'' trace a second curve, which will be the concave edge. The final directions and explanations given in connection with Figs. 46 and 47 apply equally in this case.

82. A circular seat with inclined back is shown at *a b d c* in Fig. 49. To find the length and shape of the back, let *a b* be an end section of the seat and *e h* an end section of the back; the upper line *b a* of the seat is continued to *f*, the

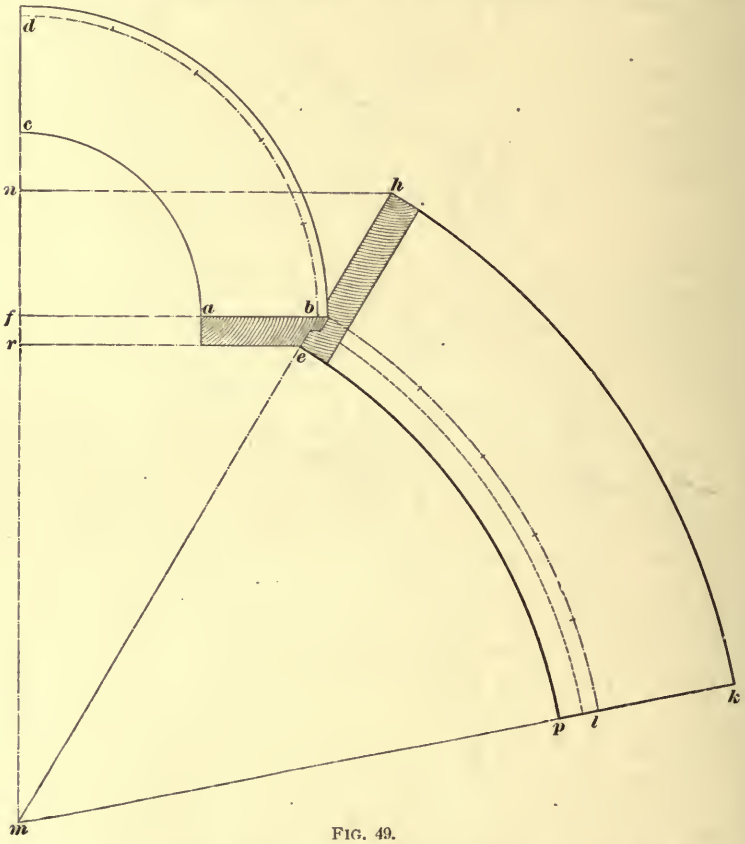


FIG. 49.

distance *b f* being equal to the radius of the back of the seat; and *f d* is drawn at right angles to *f b*. Now, with *f* as a center, and with a radius *f b*, describe the quarter circle *b d*, and with a radius *f a* equal to the radius of the front edge of the seat, describe the quarter circle *a c*. Then *a b d c* will be the plan of the seat. To unfold the length and shape of the back, prolong *h e* indefinitely, and prolong *d f*

until it intersects $h\,e$ at m; with m as a center describe the arcs $h\,k$, $b\,l$, and $e\,p$. Divide the quarter circle $b\,d$ into any number of equal parts, say five; lay off these five parts from b to l, and from m draw $m\,k$ through l; then the length and shape of the back will be $p\,k\,h\,e$.

This back must be bent, by some of the methods given, over a suitably constructed center. To prepare a center as required for bending the unfolded back, lay out $e\,r\,n\,h$, Fig. 50, to correspond in dimensions with $e\,r\,n\,h$ in Fig. 49. Draw $v\,v'$ at a distance from $e\,h$ equal to the thickness of the material of which the staves, or lagging, are to be made. Then with n as a center, and with $n\,v$ as a radius, draw the arc $v\,g'$, which will be the curve to which the upper center pieces t are to be sawed. The lower center pieces t' are sawed to the curve described with a radius $r\,v'$. The edges of the ribs must be beveled to suit the angles shown at v and v', and the lagging applied to these two center pieces brings the exterior curve up to the required form, around which the back of the seat may be bent.

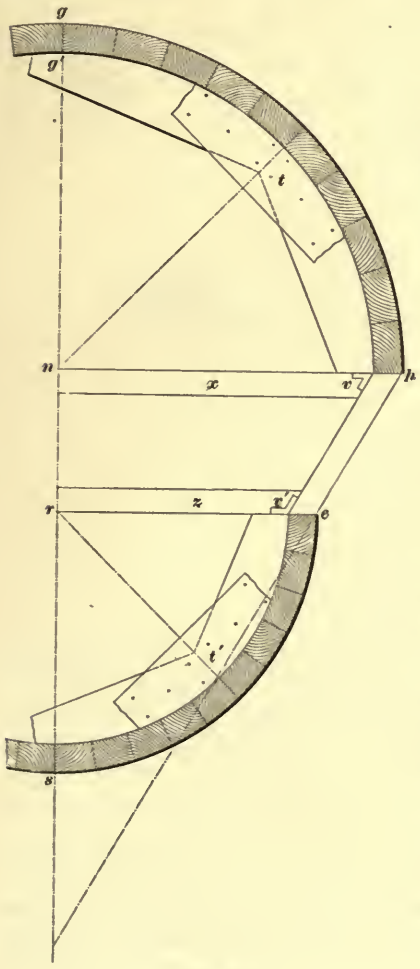


FIG. 50.

83. To miter a straight and circular molding, the straight molding to be tangent to the circular one: Let $o\,o'\,t\,t'$, in Fig. 51, be the circular molding, and x a cross-section of it; let $s\,s'\,r\,r'$ be a straight molding, with the same cross-section

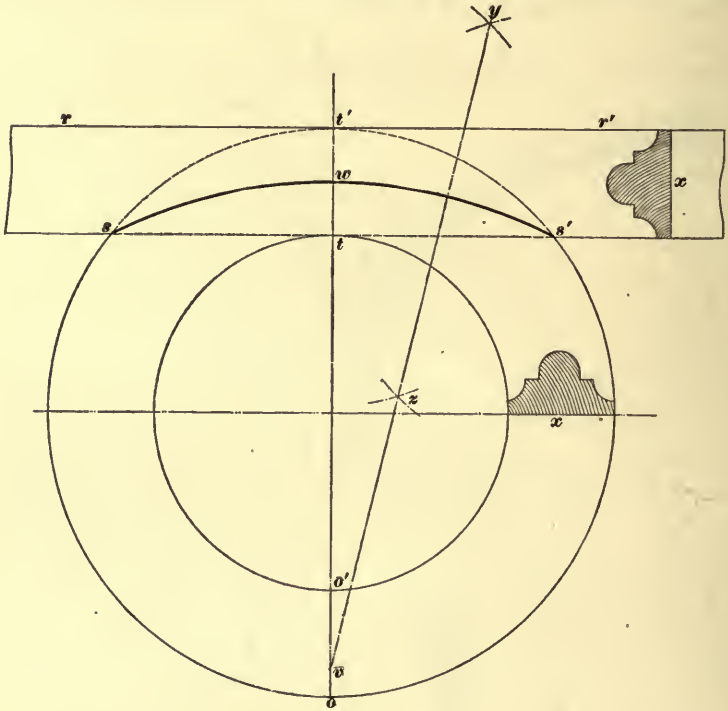


FIG. 51.

x. Bisect $t\,t'$ at w, and with s' and w as centers, describe the intersecting arcs through y and z; join y and z and produce the line to intersect $o\,t'$ in v. Now from v as a center, describe the arc $s\,w\,s'$, which will be the miter line required.

84. To miter a straight and circular molding intersecting at an acute angle: Let $b\,a'\,a\,c$, Fig. 52, be the straight molding, and $a\,a'$ the cross-section; let $z\,z'\,c\,b$ be the circular molding, and $z\,z'$ its cross-section; through the straight molding draw a center line $t\,s$; through the circular molding describe a center line $o\,s$. With c and s as centers, describe

the intersecting arcs r and l, and through r and l, draw the line $r\,y$ of indefinite length. With s and b as centers, describe the intersecting arcs at j and x, and through these points

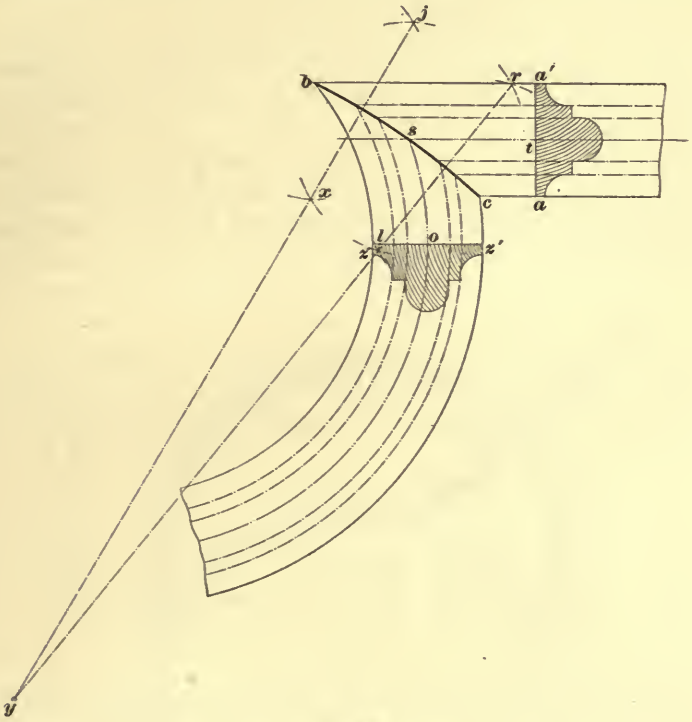


FIG. 52.

draw the line $j\,y$, cutting the line $r\,l$ in the point y; with y as a center, describe the curve $b\,s\,c$, which will be the miter line required. These miter lines on circular moldings are called *hunting miters*.

BENDING WOOD.

85. When it is required that a surface shall present a curved form, the wood may be bent around it by any one of five methods, namely, by **saw kerfing, keying, backing a veneer, laminating,** or **steaming.**

86. Saw kerfing being less costly than other methods, it is often adopted. The method is not to be recommended, however; it makes a weak construction, and no matter how perfectly the work may be done, or how well it may be painted, the saw-kerf marks will always show. For hard-wood moldings the method should never even be considered, and for curved work of whatever kind, solid molding should always be used.

A center, built to the desired diameter or curve, over which the material may be bent, and which will stay permanently and accurately in its curved form, is absolutely necessary with any of the above methods. In Fig. 53, the rib

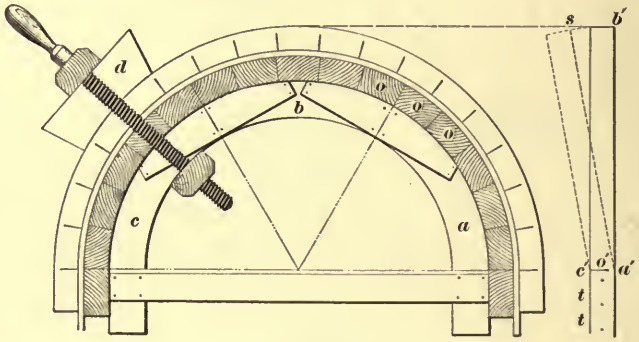


FIG. 53.

a b c for a center is composed of three pieces of $1\frac{1}{4}$-inch plank; it is made concave on its inner edge, merely because it is sometimes an advantage (when it can be done) to clutch the bent stuff and the rib with hand screws as shown. Blocks, as shown at *d*, extend the power of hand screws considerably beyond the width of the jaws, and are therefore exceedingly useful. The staves of wood *o*, *o*, *o*, etc., of any length required, are nailed to the rib *a b c*, and form the circular surface of the center. To find the distance between saw kerfs that will allow the material to bend to the curve required, take a piece of stuff of a suitable length and equal to the thickness of that which is to be bent, as at *c′ a′*, and let *a′ b′* be equal to the radius of the curve around which it

is to be bent; make a saw kerf at $c'\,o'$, leaving a thickness $o'\,a'$ from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch uncut; nail the piece at t, t; and move it from b' to s, or enough to just close the saw kerf at c'; then $b'\,s$ will be the given distance between two saw kerfs. The distance $a'\,o'$ to be uncut must be gauged along each edge of the stuff to be bent, and the same saw must be used with which the cut $c'\,o'$ was made. In this method of bending, a thin veneer is first laid, and the saw-kerfed piece is then bent over it and glued to the veneer. This is the better method of treatment in saw kerfing, but the saw kerfs may also be cut in the convex face of the stock, and when bent over the center, the veneer may be glued over the convex surface to secure it.

87. Keying.—Fig. 54 shows another method of treating material which is required to be bent. In this method grooves are made in the back of the stuff at suitable inter-

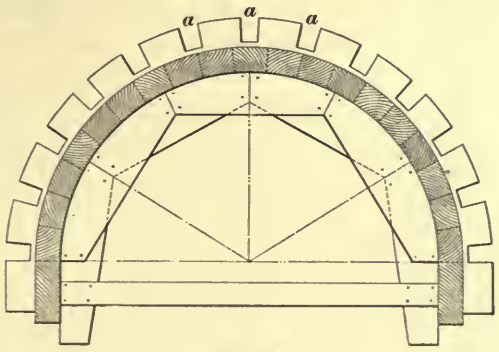


FIG. 54.

vals (found as directed for space between saw kerfs) of an even depth, as shown at a, leaving an exterior thickness of $\frac{1}{8}$ inch or $\frac{1}{4}$ inch, depending on the radius of curvature. These grooves are filled with well fitted wood strips called *keys*, plenty of glue having first been brushed in the grooves and over the keys. Two strips of veneer 3 inches to 4 inches wide, glued and nailed over the convex face of the bent piece near each edge, tend to strengthen the work materially.

The ribs of the center shown in Fig. 54 are in four parts, with bracing pieces nailed over each joint as shown.

88. Bending by **backing a veneer** is the third method, shown in Fig. 55. Enough wood is planed from the back of the stuff to be bent, to leave a veneer of the proper thickness and length between *r r*, the circumference of the semicircle; then, when bent over the center, the thickness is filled

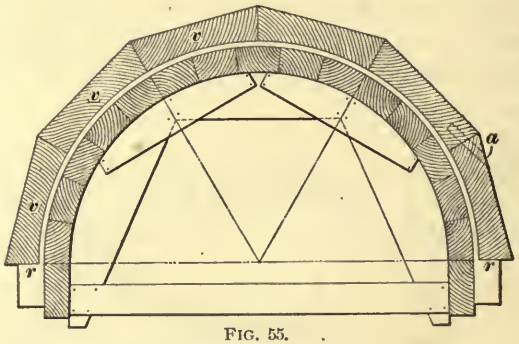


FIG. 55.

out as required by fitting and gluing on the back of the veneer the cylindrical-faced staves *v*, *v*, *v*, etc. These staves are made a little long, and each one, after being fitted and glued, has a long screw driven through its thickness to the center, near each end, to hold it down and keep it in place until all are fitted and glued. To increase the strength of this curved piece of work, before taking it off the center, the joints may be united by hardwood dowels, glued and driven in as shown at *a*.

89. **Laminated Curved Work.**—The fourth method, as shown in Fig. 56, is a mode of bending and gluing together several layers, as shown at *a*, to make up the required thickness. These should all be fixed and glued over the center at one operation, and, if possible, left there some days to dry out. This is by far the strongest and best method of all for most purposes; but it will not do for moldings, as the

edges in hard wood, when cut into, show the streaks of glue;

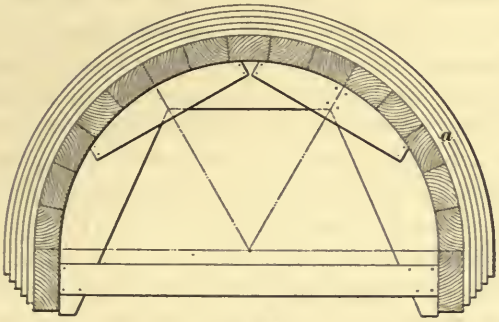


FIG. 56.

this, however, would be unobjectionable where the work is to be painted.

90. The fifth mode of bending is by **steaming.** Some woods bend easily when steamed, but all must be handled with rapidity after steaming, allowing no time for cooling until after the work is secured to the center. A good steam box of suitable size must be prepared and wet steam must be used, since dry, superheated steam makes wood brittle but not flexible.

To find the thickness of white pine (without preparation) that may be bent without injuring its elasticity, *multiply the radius in feet of the curvature required, by the decimal .05, and the product will be the thickness in inches.* For example, take a 5-foot radius; multiplying this by the given decimal, the thickness that will bend without fracture is $5 \times .05 = .25$ inch $= \frac{1}{4}$ inch.

VENEERING.

91. Hard woods, such as oak, ash, rosewood, etc., cannot be used in joiners' work, where the pieces are of any considerable dimensions, unlesss they are backed up with some lighter or more reliable wood which is less affected by moisture or change of temperature. The hard wood is, therefore,

usually cut in thin slabs and glued to a piece of pine or other soft wood, in such a manner that the finished work has the appearance of a solid block; while in reality its interior or core is of an entirely different material. This process is called *veneering* and the thin slabs of hard wood are called *veneers*. It is a mistake to suppose that veneering is resorted to as a matter of economy, to save the enhanced cost of solid wood. Hard woods are liable to warp or twist out of proper shape. Especially is this the case with doors built of solid hard wood; and so it becomes absolutely necessary, in order to make a good door and secure the decorative elegance in color and grain of the hard woods, to employ veneering in door making; this properly done with good glue will last as long as the wood upon which the veneer is laid.

It is not good practice to use two kinds of wood in veneering a door; as one face mahogany, the other oak; or maple and cherry; oak and black walnut, etc. The varying conditions of the atmosphere, heat, and moisture act differently upon the two kinds of wood, and the doors have a tendency to warp. This is equally the case with a door where one face is in a warm room and the other face constantly exposed to different atmospheric conditions, even though both sides of the door are veneered alike. If only one side of a panel is veneered, it will curl badly when dry; consequently all veneering should include both sides.

The choicest and most beautiful veneers are cut from the crotches, and also with some woods from the roots of the trees, where the grain is gnarled, mottled, and attractively intermingled. These choice veneers are used on the surfaces of panels, and are highly polished to bring out the beautiful, natural changes and color qualities peculiar to the wood; this is relieved by the less-polished plain surface of the framework. The frame, or stiles and rails, are invariably veneered with plain straight-grained veneers finished flat.

92. There are several valuable accessories to good veneering which must not be overlooked. The first of these is a good heating box, of a length and width sufficient for long

and short materials. Such a box may be cheaply constructed of plank, and lined with tin, with its cover or lid in three sections; the box should be piped and heated by steam, or in the absence of steam it may be heated conveniently by a 6-inch stovepipe carried through it lengthwise. In all cases heated cauls are used against veneer to keep the glue hot, so that the wood may the better absorb it. The caul also distributes the pressure of the hand screws on the whole surface of the veneers evenly, during the several hours required for the glue to set. A *caul* is a piece of wood or other suitable material curved or straight, as the case may be, to fit the surface to be veneered. When used for door stiles or panels, a thickness of 1 inch will be sufficient, and its width and length should never be less than that of the material to be veneered. To prevent the caul from sticking to the veneer, it should be coated with beeswax or paraffin; or, in the absence of these substances, brown paper cut to size will serve the purpose if laid between the veneer and caul; brown soap is sometimes used, but frequently stains the wood.

93. In door making, the core should be clear white pine; the stiles are built up of several strips, the grain of each being reversed with reference to that of its neighbor, and all glued together. The edges of the stile have hard wood glued on as required; the stile is then faced straight out of wind, and is well scratched lengthwise by means of a toothed plane; and the veneer should also be scratched. The glue should be well cooked—if burned it is useless—of a good body not too thick, and plenty of it should be brushed on the surfaces which are to be in contact, as the wood absorbs considerable of it. In Fig. 57, at (*a*), is shown a section through a door stile such as described; the caul is seen at *a* against the veneer *b*, while the core is shown at *c*. Several stiles or rails may be veneered at one time with only outside cauls, but with paper between the veneers. The veneers require to be tacked in two or three places to keep them in position until clamped together with hand screws, which should be spaced

not more than 6 inches apart—in fact they can hardly be put too close together. The hand screws are placed

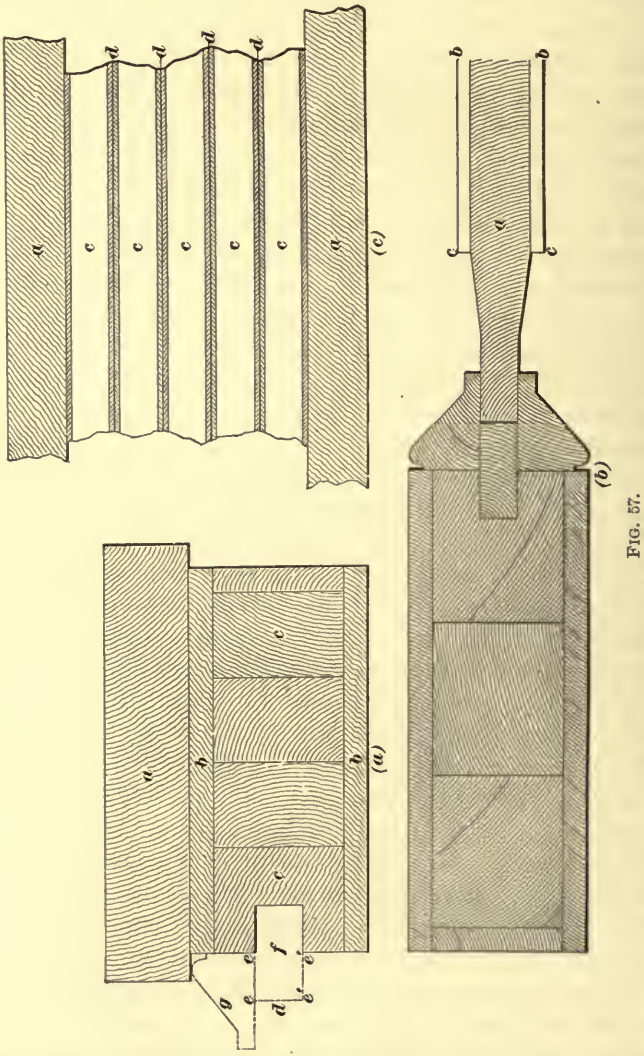


FIG. 57.

at opposite sides alternately, to insure an even pressure on both edges, which drives the glue into the pores of the

wood. In paneled work, where hard-wood moldings are used, it is desirable to avoid the use of nails to secure the moldings in place.

At *f*, Fig. 57, is shown a pine strip glued into the groove of the door stile, against which the panel moldings *g* are mitered and glued at *e e*; then the polished panels are set in place at *d*, and the other face of the door is molded and glued to *e' e'*. Another example of door-stile molding and panel is shown at (*b*); the panel *a* is usually made of the same kind of wood as the veneer, but plain; sometimes, however, the raised face *b c* is veneered with choice wood of finely marked grain, polished and finished before it is placed in the door. All plain-faced material may be clamped and veneered together in quantities, as shown in Fig. 57 (*c*). The core pieces *c*, *c* are separated by layers of paper between the veneer faces, as seen at *d*, one operation with the hand screws and two cauls *a*, *a* sufficing to secure the whole.

94. Thin veneers are often found in a badly crumpled condition. In this case, they must be sponged with hot water and squeezed gradually and evenly with hand screws between plane-surfaced cauls, and left several hours or over night, until they are in a fit condition to be laid. Sometimes heavy weights placed on a caul over the moistened veneers are sufficient to accomplish the same effect.

95. To join two pieces of thin veneer together, they must be cut with a sharp knife, guided by a perfect straight-edge. The pieces are laid upon a plane surface with paper underneath, and are tacked at a convenient distance on each side of the joint in such a way as to draw the two pieces together; then a strip of strong Manila paper is glued over the joint, and the veneer is placed on a suitable straight strip of wood under heavy pressure and allowed to remain until the glue is dry. In laying this jointed veneer, the papered side must be laid outwards.

96. The veneering of a small circular column may be accomplished as shown at Fig. 58. Here a sheet of tin is used, having cleats securely nailed to each end by which hand screws can be made to press the heated tin caul and veneer tightly to the surface of the column. The tin should be about $\frac{3}{4}$ inch shorter than the circumference of the column, in order to leave room for the glue that is squeezed out along the joint. The veneer should be sponged with hot water just before straining it around the column. The column and the tin should be heated before veneering. The advantage of a tin caul is that it requires no waxing, and will not stretch. A strip of paper wrapped around the core will be sufficient to determine the length of the veneer, which must be equal to the circumference of the column. To bring the two edges of the veneer together when the tin caul is removed, long solid cauls are used, as shown at *s* in Fig. 59.

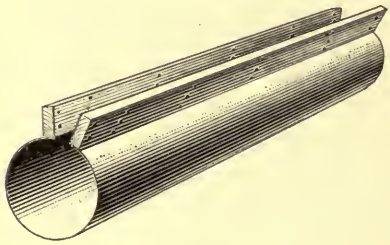


FIG. 58.

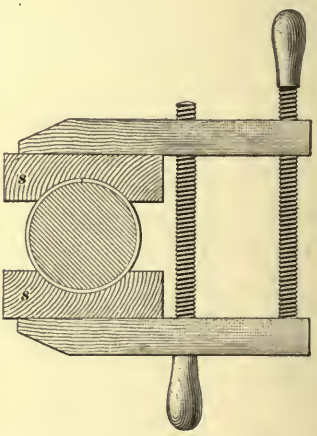


FIG. 59.

97. A tapering column is veneered in precisely the same manner, but to find the length and shape of the veneer, lay out, as in Fig. 60, *a b* equal to the height of the column and *c d* equal to the base; continue *c e* and *d e* to *i*; from *i* as a center, with *i c* and *i e* as radii, describe the arcs *c h* and *e f*; from *a* as a center, describe the semicircle of the base *c d*; divide the semicircle into any number of equal parts, and mark these parts twice on the unfolded base line

ch; connect hi; then $chfe$ will be the shape and exact

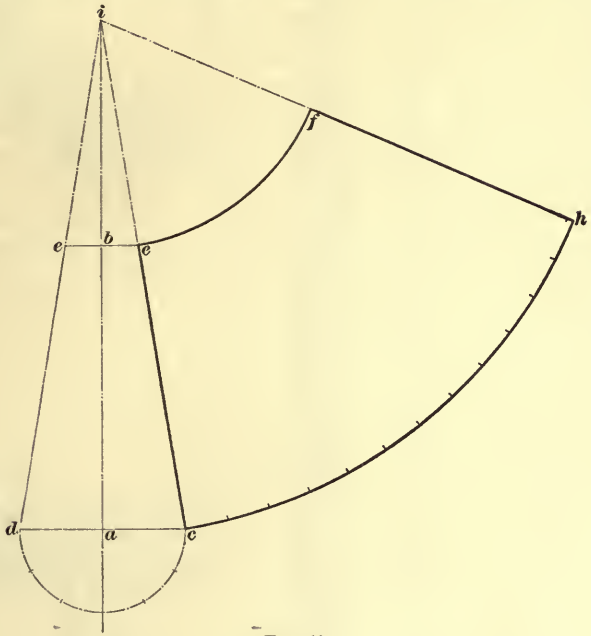


FIG. 60.

length of the veneer, also of the caul; this, however, must be made to come together about $\frac{3}{4}$ inch short, as previously explained.

BLINDS.

98. In order to prevent the strong sunlight from streaming through the windows of a dwelling or other structure, these openings are usually provided with **blinds,** or **shutters,** which may be of several different forms, or combinations of two or more forms. Blinds are divided into two general classes, namely, *inside* blinds and *outside* blinds. The former may be either *folding* blinds, or *rolling* or *Venetian* blinds, while outside blinds are nearly always of the same general pattern, and are known as *shutters.* The method of construction in each case is influenced largely by atmospheric conditions, but the general principle is the same

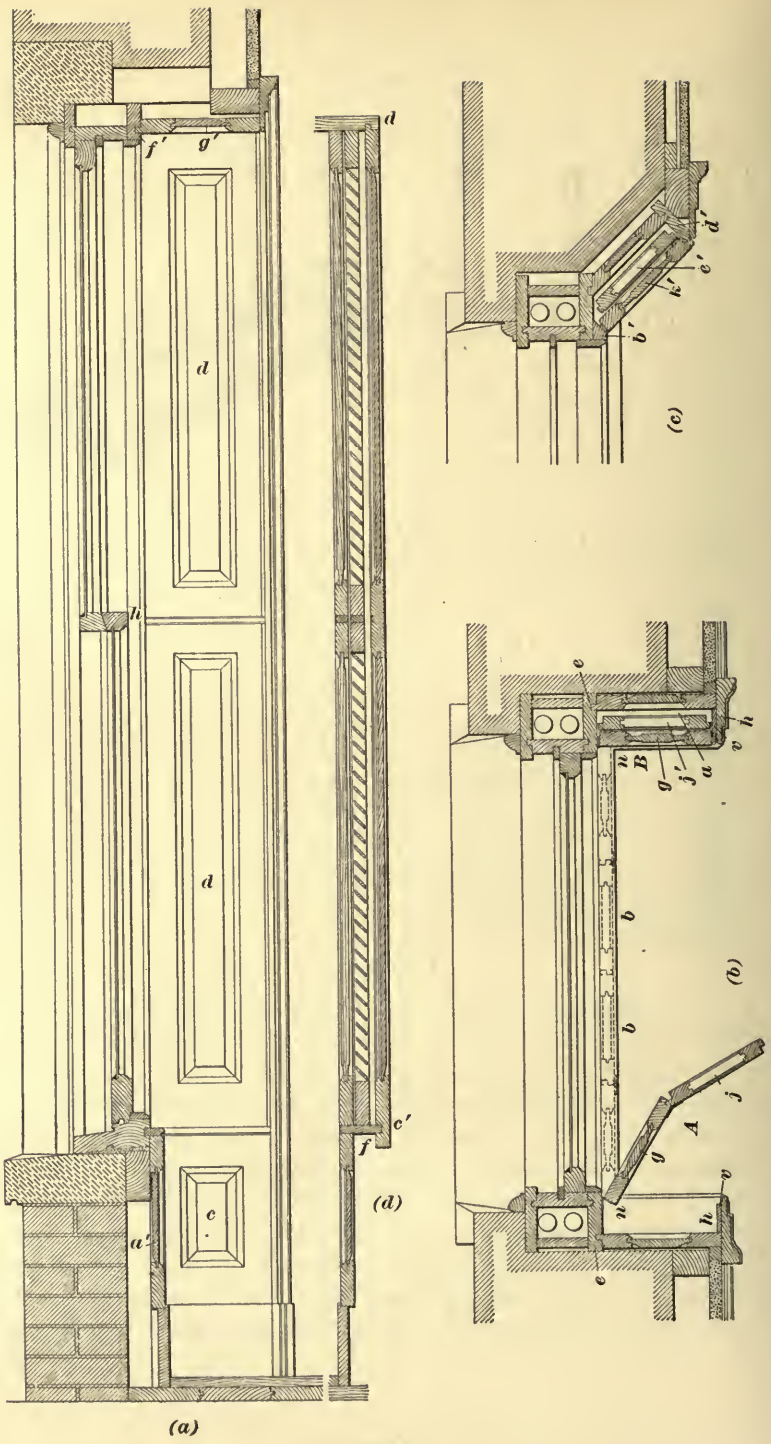


FIG. 61.

in all cases. Inside blinds are usually made of hard wood to match the trimming of the room containing them, while outside blinds are nearly always framed of pine and painted to protect them from the elements. Outside blinds must also be constructed with consideration of the fact that they are likely to be subjected to rather rough usage through the influence of high winds and rapid changes of temperature.

99. Inside folding blinds make a very neat, as well as a most useful fitting for the inside of a window, and they should be so arranged that, when closed into their box, the exposed blind will show a panel finish on the inside of the room, as shown at *d*, Fig. 61 (*a*). These shutters are usually built in a square jamb, as shown in the plan, Fig. 61 (*b*), though, when circumstances will permit, they may be built in a splayed opening, such as is shown in Fig. 61 (*c*), in which case the panel work shows up to better advantage, and the room is rendered lighter.

In Fig. 61 (*b*) the full plan of the window is shown with the shutters closed into the box at *a*, while the dotted lines at *b* indicate the position of the shutters when opened out of the box and closed over the window sash. The extreme width of the shutters between the outside hanging stiles *n* is $1\frac{1}{2}$ inches more than the width of the window between the pulley stiles, and is divided into four parts, each one of which represents the width of a leaf, or wing of the inside blinds. Two of these leaves are usually paneled, as shown at *g*, and the other two are provided with fixed or movable slats, as shown at *j*. The slatted portion is hinged to and folds behind the panel, as at *A*, and the two then revolve on hinges connecting the paneled leaf to the casing and close into the box with the panel on the exterior as shown at *B*.

These blinds are framed together in one piece, from the inside sill to the window head, in the same manner as the rails and stiles of a door, except that the outer leaf *j* of the blinds is filled with fixed or movable slats or louvers, instead of paneling, as is the inside leaf as seen at *d*, Fig. 61 (*a*).

The space between the sill of the window and the floor is

usually covered by a *panel back* shown in section at *a'*, Fig. 61 (*a*), and its return under the blind box is shown at *c*. This panel back is usually paneled similarly to the blinds above, and is constructed in the same manner as the paneled shutters.

At (*d*), Fig. 61, is shown a section through the panel back and blind box; at *f* is seen the bottom of the box, housed into the lining *c'*, which forms the back of the inside of the blind box and is secured at the top by a tongued-and-grooved joint into the soffit piece *d*. This soffit piece *d* is paneled to match the blinds and panel back in the jambs, as shown at *g'*, Fig. 61 (*a*), and is secured by a tongue worked on its edge and let into the window casing at *f'*. The inside lining *e* of the weight box, Fig. 61 (*b*), in the window frame, forms the outer lining of the shutter box, and the inner lining of the latter, as shown at *h*, is attached to and forms a part of the interior trim. The paneled blinds *g* are hinged to the hanging stile as shown at *n*, while the slatted blinds *j* are hinged to *g*, so that the knuckle of the hinge is entirely within the edge of the stile of *g*. This method of hanging permits the blind *j* to swing back sufficiently from the edge of the stile to secure it against any danger of catching on or against the edge of the architrave, or the blind stop *v*, when the blind is closed into the box as shown at *B*. This is still further accomplished by making the blind *j* $\frac{3}{4}$ inch narrower than *g*, so that there will be no tendency for it to become jammed in the box. The rabbeted joint between the two blind flaps *g* and *j* is only $\frac{3}{8}$ inch deep, and is provided simply to secure a light-tight joint.

100. When the jambs of the window are splayed, as shown in Fig. 61 (*c*), there is but a slight difference in the construction of the blinds themselves, though the box requires a little extra attention. At the outside edge of the box, on the side next to the window, the extra hanging stile *b'* is introduced, to provide at the front edge of the box a proper depth for the paneled shutter *k'* to shut into, as without it the blind would close back no further than in the square jamb shown in Fig. 61 (*b*). The box jamb *d'* is also necessary at

the inner side of the box, to form a satisfactory stop for the blinds, and to make a neat finish to the box itself. In splayed window jambs, the blind *e'*, which folds inside, must be made from $1\frac{1}{2}$ to 2 inches narrower than the exterior blind *k'*.

101. When inside blinds are required for a window, it is first necessary to lay out a measuring rod with the stiles, rails, and panels marked as described for the framing of doors, etc. The entire blind, from the sill to the window head, is laid out and constructed in one piece, and then sawed apart at the center of the meeting rails, as shown at *h* in Fig. 61 (*a*). The shutters are temporarily hinged and hung in place, so as to insure their proper fit, and the marks are then made at the meeting rails, to which the blinds are afterwards sawed, thus forming a separate set of shutters to cover the upper and lower sashes independently.

102. Outside blinds differ from inside blinds only in such details of construction as their more exposed situation requires. Fig. 62 shows at (*a*) the inside elevation of an outside blind, and at (*b*) is shown its plan. The hanging stile for the blind on the window frame is shown at *c*, and the form of hinge necessary to permit the blind to open around the angle of the brickwork is shown at *b*. The shape of this hinge and its attachment to the shutter is shown by the dotted lines at *f*. The angle in the hinges permits them to extend over the joints at the top and bottom rails, and adds strength to the shutter, besides rendering it more secure in high wind storms than would the ordinary hinge.

The extreme length of the arm *o b*, carrying the pin half of the hinge, permits the shutter to swing around the outside of the brick wall clear of the opening, as shown by the dotted lines, but the corresponding length *o d* causes the blind when opened to move first in the direction *d a*, and is likely to cause the shutters to bind when they are opened. This tendency, however, is compensated by the thinness of the metal of which the hinges are made, as they can be easily *sprung* out of place a sufficient distance to permit the blinds to open at the center and swing clear.

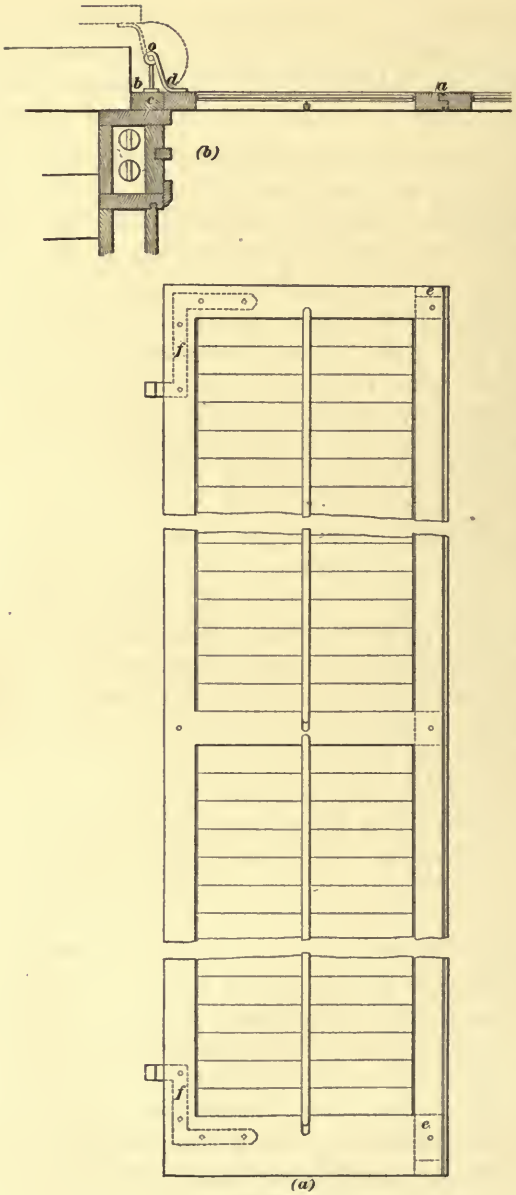


FIG. 62.

103. Outside blinds are laid out with a measuring rod, in the same manner as doors and other framed work, the lengths of stiles and rails, the positions and lengths for tenons, and the location of relishes, etc. being all marked on the measuring rod before any of the actual framework is even started. The positions and proportions of the mortises and tenons in this blind are shown by the dotted lines at *e*, as are also the tightly driven pins which hold the joints in place.

As glue would be useless to secure the joints of outside blinds, owing to their exposed situation, the fixed parts are put together with white lead, as described in Art. **193,** of *Carpentry*. The movable joints of the slats, however, require nothing to make them secure, except a proper consideration for the accuracy of construction and the effects of probable expansion and contraction.

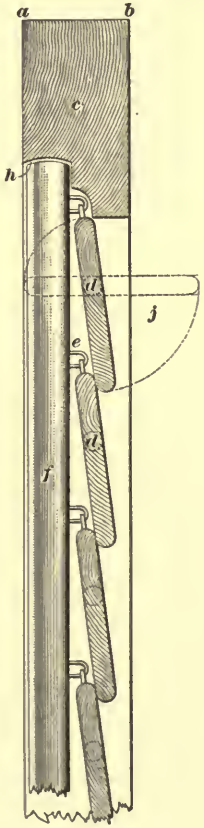


FIG. 63.

104. Fig. 63 shows a section of the top rail of the shutter and four of the slats, or louvers. The thickness *a b* of the stile varies, but is never less than $1\frac{1}{8}$ inches, and the holes shown dotted at *d* are the same in diameter as the slats are in thickness, which thickness varies with the size and weight of the blind. The holes are bored from $\frac{3}{8}$ to $\frac{5}{8}$ inch from the outside of the stile, and should be exactly $\frac{1}{4}$ inch deep. The pins on the ends of the louvers are exactly $\frac{1}{8}\frac{1}{2}$ inch in length, thus leaving at each end of the slats $\frac{3}{8}\frac{2}{2}$ inch to allow for painting, and to permit freedom of movement.

The louvers are operated by a rod which is attached to each slat by means of two U-shaped staples, one of which is forced into the middle of the edge of the slat, and the other driven

into the rod itself, as shown at *e*. Thus, when the rod *f* is pulled down, each of the louvers is thrown to the horizontal position shown by the dotted lines *j*, thereby admitting light and air through the blind.

The top stile *c* is cut out, as shown at *h*, to receive the upper end of the rod *f* and the upper staple when the slats are closed in the position indicated in the illustration.

Blinds of this character are made with two, three, or four panels of louvers, according to the height of the window on the stile of which they are hung, each panel being separated by a horizontal rail from the one next above or below, and each set of louvers being operated by a separate rod, as shown in Fig. 62, except in the case of an unusually high blind, when the upper two sets are sometimes operated by one long rod extending over both panels, and moving in a groove cut across the separating rail when the slats are closed.

HINGES AND THEIR APPLICATION.

105. Butts, or hinges, are used in hanging doors, inside shutters, lids of chests, boxes, etc. The butt generally used in hanging doors is a loose pin butt; the pin being loose, it can be readily taken out with the fingers, and the door can thus be removed without unscrewing the hinges. To properly hang the door, two hinges, and in case of heavy doors three hinges, are required, the top one being secured 6 inches below the top of the door, and the bottom one, 10 inches above the bottom of the door. Fig. 64 (*a*) shows a horizontal section through the door casing at the hinge. At *b* is the door jamb, back of which are the grounds *f*, extending to the plaster line *j*; *c* shows the door trim, and *g* shows the door stop, against which the door *a* is closed; the projection of the hinge *s i* to the center of the pivot is the same as *s' i'* of the elevation of the hinge shown at (*b*), where one flap of the hinge is seen let in and screwed to the edge of the door. This projection of the hinge *s' i'* when the door is opened, as shown dotted at *e*, causes the door to swing twice

the distance $s'i'$, thereby causing it to clear the trim c—a condition always requiring consideration when ordering the hinges.

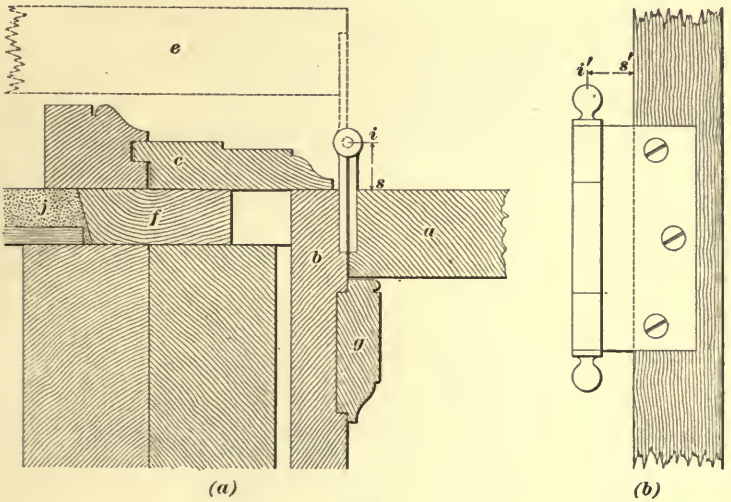


FIG. 64.

106. Fig. 65 shows an inside window-frame casing at e, to which the elbow shutter b is hung. The shutter as it stands in the box is shown at b; while at a it is shown dotted in position as closed across the window; c shows the flap shutter in line with b when open, and d shows its position when folded in the box. In hinging the elbow shutter b to the casing e, the whole thickness of the hinge is let into the edge of the shutter, and the flap of the hinge is screwed to the face of the casing e. The knuckle of the hinge should just project beyond the face of the shutter b, as at z. When the hinge is placed as shown, making $a'b'$ $\frac{1}{2}$ inch from the edge of casing to face of shutter, then, when b swings on its hinges to the position a, the edge of the shutter will be at c', which is $\frac{3}{16}$ inch from b', or $\frac{11}{16}$ inch from a'; therefore, in making the shutters, the width must be taken from c' in order to show the $\frac{1}{2}$-inch margin of the casing when the blinds are open. The flap hinge ifj is screwed to the inside face of

the shutters—keeping the knuckle of the hinge all on the elbow shutter *b*; this is done to prevent the edge of the flap

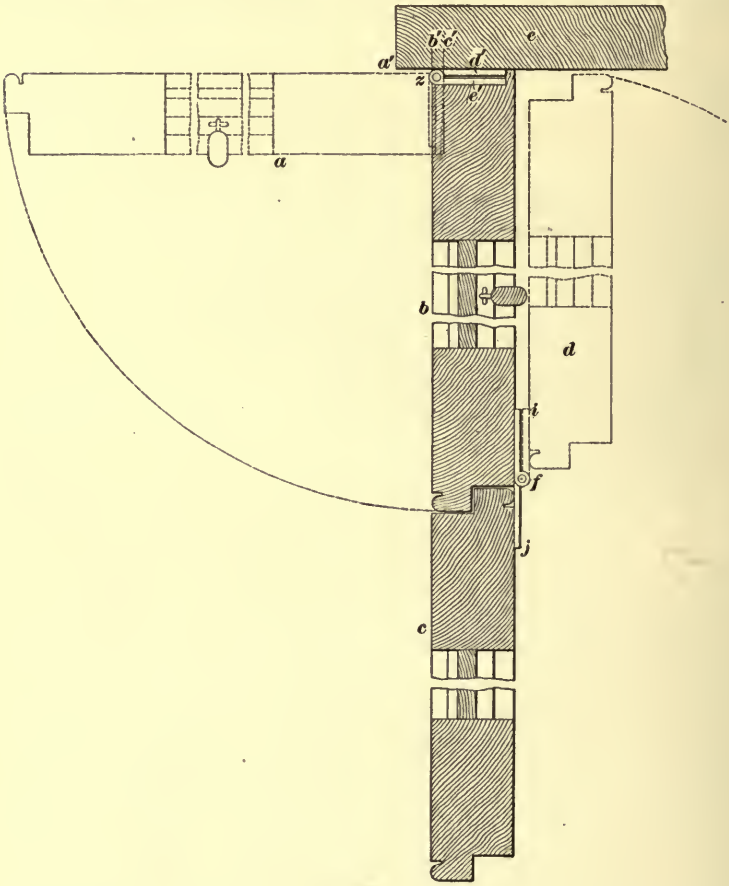


FIG. 65.

shutter *d* from striking, when folding the two shutters in the box as previously explained.

107. Hinging Outside Blinds.—Fig. 66 shows a plan of the blinds of a frame house; *b* shows the position of the blind shutter when closed, and *c* shows the blind shutter opened; at *a* is seen the hanging stile to which one-half of the hinge is screwed, as shown at *h*. The hinge is in two

parts, shown at (*b*), and consists simply of an iron strap *d* with a socket to fit around the pivot *f* which is secured to the other half of the hinge; at *s* is seen the edge of the iron

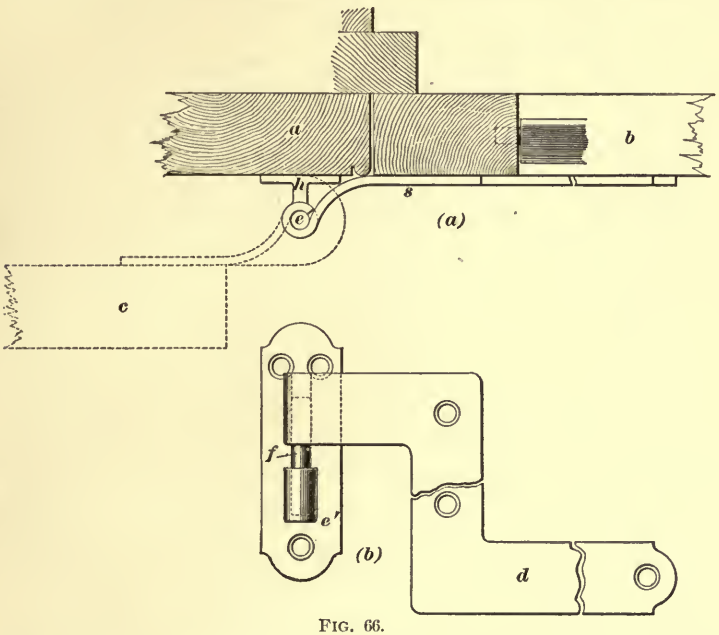


FIG. 66.

strap *d*, which is screwed to the blind *b* and with the pivot *f* in the socket *e*.

Outside blinds of brick houses require a hinge very little different from that of a frame house, but the hinge must throw the blind out farther, in order to clear the brick corner.

INTERIOR FITTINGS.

108. Though the location of the fixtures and the arrangement of the pipes in the bathroom are usually considered only in connection with the plumbers' work, the finish of these details and the general interior treatment of the rooms are entirely in the hands of the joiner.

Fig. 67 (*a*) shows the front elevation of the enclosure around

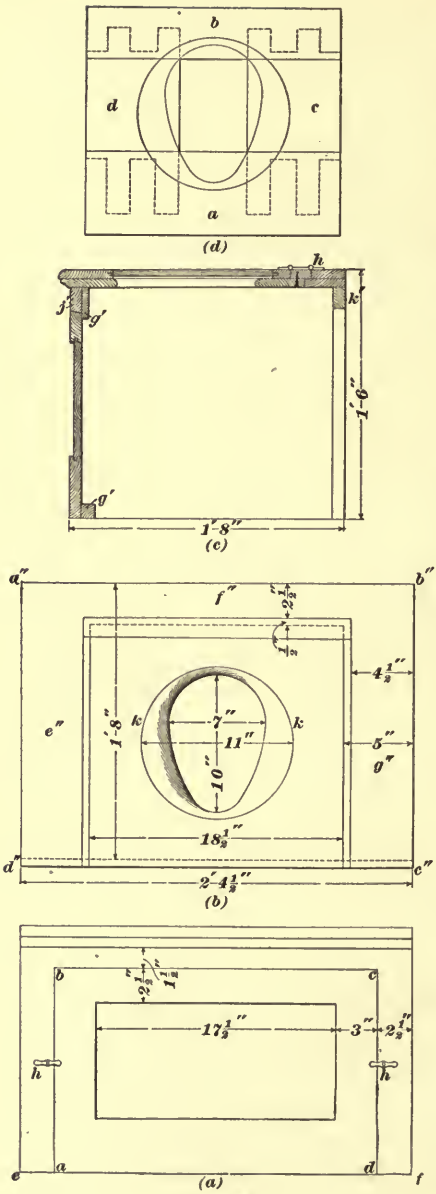


Fig. 67.

the water-closet seat, when such an enclosure is required by the character of the plumbing. The paneled front *a b c d* is framed of $\frac{7}{8}$-inch stock, and enclosed at the top and ends by the casing *e a b c d f*, on the back of which are provided the stops, shown at *g'* in the section (*c*), to prevent the panel front from falling inwards, while the two thumb buttons *h*, Fig. 67 (*a*), hold it securely in place, but at the same time permit of the front being readily removed to examine the plumbing fixtures.

On top of this front framework is the seat and its cover, or lid, each of which is hinged, so that it may be raised when necessary. This is accomplished as shown in the plan (*b*), where *a" b" c" d"* is the outside framework covering the entire top of the water closet and extending the full width of the enclosure, which is usually 2 feet

4½ inches, as shown. This framework consists of three side pieces *e″*, *f″*, and *g″*, and is screwed to the back cleat, shown at *k′* in (*c*) and to the front panel frame *j*. Within the opening of this frame is fitted the seat *a d b c*, framed of four pieces, as shown at (*d*), the front and back pieces *a* and *b* being mortised on their inner edges to receive the tenons and relishes of the side pieces *c* and *d* as shown by the dotted lines. The opening in the seat is formed at the back with a semicircle 7 inches in diameter, and at the front with a semiellipse whose semimajor and semiminor axes are 6½ inches and 3½ inches, respectively, making the opening 7 in. × 10 in., as shown at (*b*). This opening is splayed out on top and rounded over to the line of a circle *k k* whose diameter is 11 inches. The seat is hinged at its back to the back of the framework *a″ b″ c″ d″*, as shown at *h* in Fig. 67 (*c*). The lid or cover is then made 1 inch wider, but 1½ inches less in depth than the seat, and is fitted over it and hinged to cleats on the top of the framework, as shown. The lid is framed in the same manner as the seat shown at (*d*), but with the opening omitted and with a flush panel inserted in the center; or it may be a plain board with clamps on the end, as described in Art. **19.**

109. **Washtubs** are fixtures which the joiner is frequently called upon to build, and Fig. 68 shows a method of constructing them. At (*a*) is shown a plan of one of these tubs, at (*b*) a vertical section through the tub, and at (*c*) the plan of the cross-piece under the tub, and its joint with the turned leg, as seen at *x* in the vertical section. These fixed tubs are usually built either in a kitchen or laundry, and consist of from two to four divisions. At (*a*) is shown the end tub of a set. The partition *a* and end-piece *b* are seen housed into the front and back pieces *c* and *d*. These pieces *a*, *b*, *c*, and *d* are all 2 inches thick, and are bedded at the joints with white lead. The bottom is dadoed into the sides and secured by means of lagscrews, shown at *e* in Fig. 68 (*b*), and this joint is also set in white lead. At *y y′* is seen a

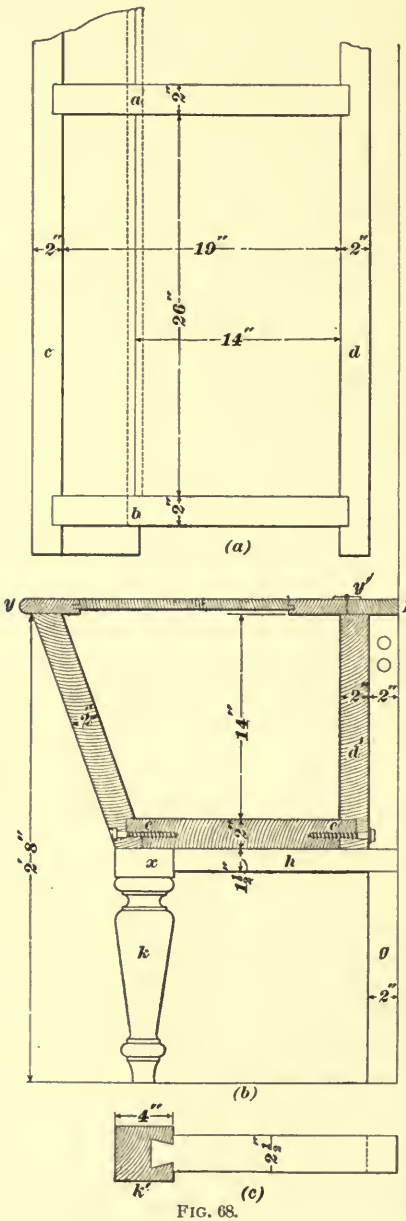


FIG. 68.

paneled cover over the tubs, hinged with a brass hinge at y', while behind the tubs is shown a 2-inch space for pipes, etc. Extending over three-fourths of the thickness of the back piece d' is a wooden cap f, which finishes the top against the wall. At g is shown a $2'' \times 2\frac{1}{2}''$ support against the wall, carrying one end of the $1\frac{1}{2}'' \times 2\frac{1}{2}''$ beam h, the other end of the beam resting on and dovetailed into the 4-inch leg k, as shown in the plan (c) at k'.

110. Butler's Pantry.—There is no part of a private residence where the joiner is called upon to do so much work in a small space as in the butler's pantry. The pantry must contain a long table for the reception of the dishes, both before and after their service in the dining room; and a sink, well lighted from an adjacent window must be provided, in which to wash them, while a dresser opposite or over the long serving table will receive the dishes after they have been washed.

Fig. 69 shows the plan of a butler's pantry such as might exist in any private city house, the details of which would be applicable to any other residence, either city or suburban. The entrance *a* is provided with a sliding door, for economy

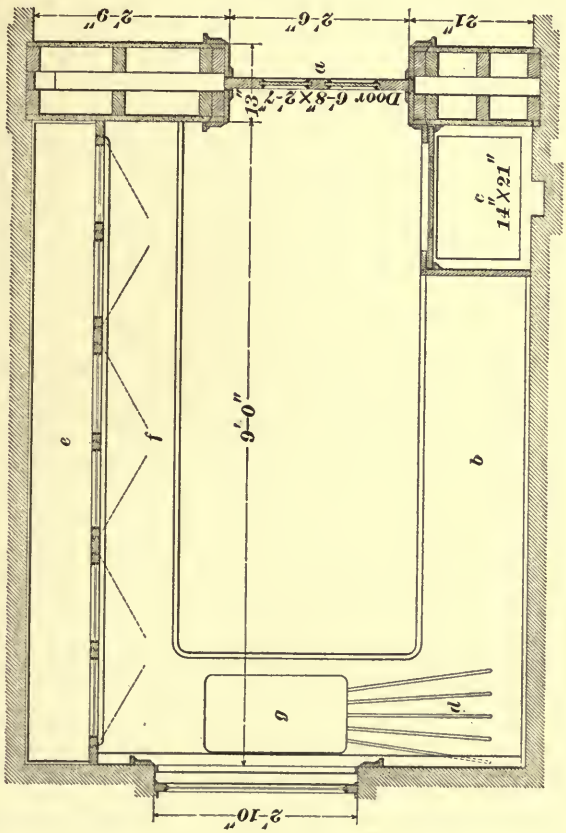
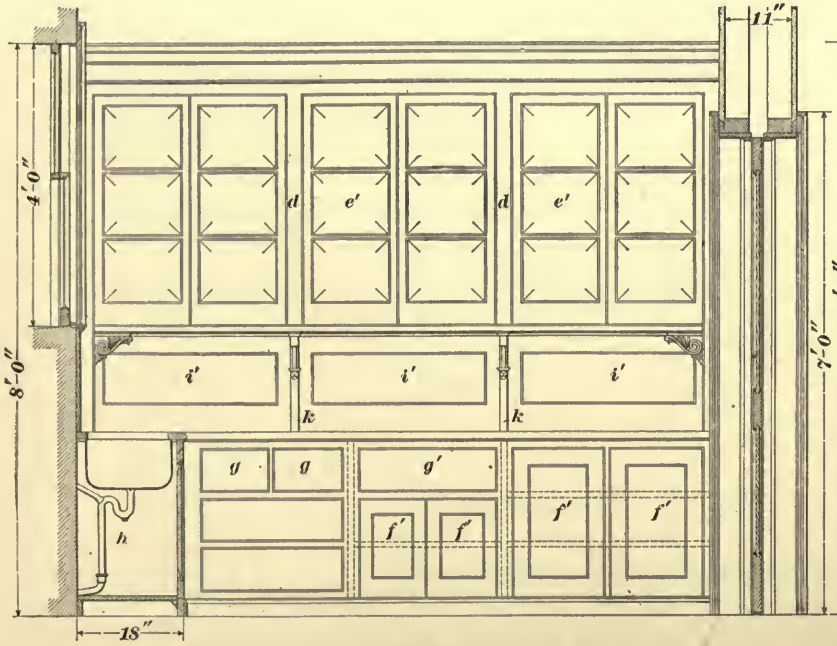


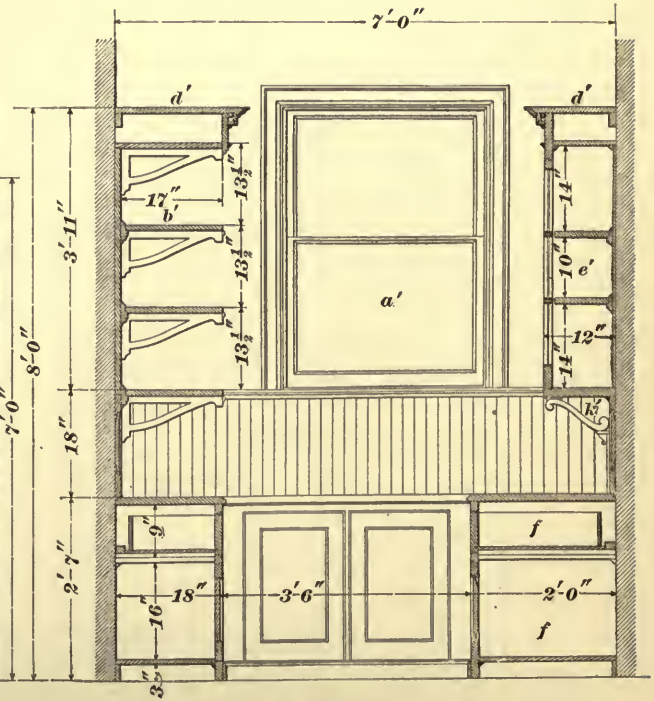
FIG. 69.

of space. On the left at *b* is the long service table 18 inches wide, where the dishes are placed or the carving is done before the food is served in the dining room. At one end of this table is the dumb waiter *c*, while at the other end, at *d*, is the drip board of the sink. Opposite the serving table is *e*, the dresser for the dishes, below which are closets *f*,



11″
4′-0″
8′-0″
d
e′
d
e′
i′
i′
i′
k
k
g
g
g′
f′
f′
f′
f′
h
18″
7′-0″
8′-0″

FIG. 70.



7′-0″
d′
d′
17″
b′
13½″
13½″
13½″
a′
14″
10″
e′
12″
14″
k′
3′-11″
18″
2′-7″
9″
16″
3″
18″
3′-6″
2′-0″
f
f

FIG. 71.

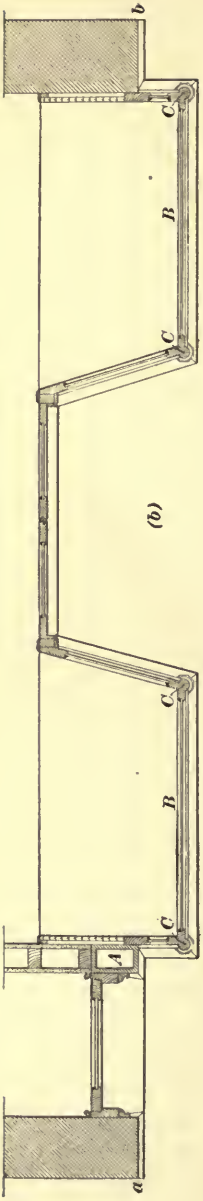
and drawers for silverware, dishes, etc., as shown more in detail in Fig. 70.

111. There is no work in the construction of these pantry fittings that has not already been described. The glazed doors of the dresser *e'*, Fig. 70, are constructed in the same manner as a hinged window sash. When the dresser is not over 7 feet long, it is sometimes advantageous to close the front with three glazed sashes, which are plowed with a groove in the top and bottom rails, and are arranged to slide the full length of the dresser on hard-wood or metal tracks, which are secured just far enough apart to permit the sashes to clear one another in sliding. Or they may be made in pairs and hinged as shown on the elevation. The shelves in the dresser may be fixed permanently in place and varnished on both sides, so as to prevent any dust from sticking to them or collecting around the dishes. The drawers *g'* are provided for silverware, such as forks, knives, spoons, etc., and the shelves in the closets underneath are for linen and larger pieces of tableware, which cannot conveniently be put in the upper part.

The glazed closets *e'* are placed about 18 inches above the top of the linen closets *f'*, thus leaving a long narrow sideboard between, the wall side of which is paneled, as shown at *i'*, with plain, flat, unmolded panels, similar to those in the doors below. The glazed closet is secured against the wall, but is supported by means of metal or wooden brackets *k*, placed one at each end of the closet and one under each of the mullions *d*.

In the section shown in Fig. 71, the window at the end of the pantry is seen at *a'*, and immediately under the window is the sink, as shown at *g* in Fig. 69. The board shelves over the serving table are seen in section at *b'*, Fig. 71, and a section through the dresser shelves is shown at *e'*.

When the pantry is built in a suburban residence, it partakes more of the character of a storeroom, and requires at least one chest of smaller drawers, as shown at *g* in Fig. 70, for the stor age of coffee, tea, sugar, spices, etc., while at one end must be provided a proper compartment for a barrel or bag of flour.



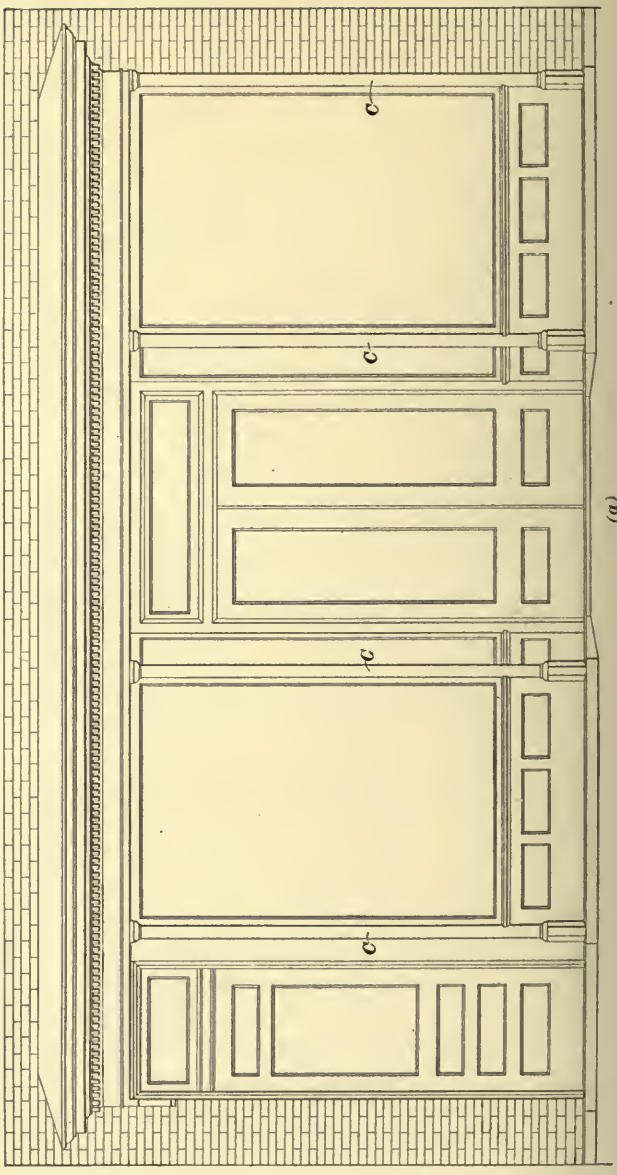


FIG. 72.

EXTERIOR JOINERY.

112. Store Front.—In Fig. 72 (*a*) is shown the treatment usually given a store front, to provide a proper entrance to the store, adequate display windows for goods, and a private entrance to the hallway which communicates with the rooms or apartments over the store. The illustration shows a building 25 feet wide, the side walls of which are of brick 16 inches in thickness, and are built out to the line *a b*, in (*b*), leaving the entire front of the structure, on the ground floor, to be constructed of framework and glass. The brick wall above the first story is carried upon a steel girder, which extends entirely across the building from one side wall to the other, and is set with its outer edge on the building line *a b*. A private entrance and hallway is partitioned off 3 feet from the left-hand side, and the partition separating this hallway from the store abuts an iron column *A*, which, by giving additional support to the girder, materially shortens its span.

113. As the construction of a frame and transom sash, the framing and hanging of a door, etc., as herewith required, have all been previously considered, we will confine our attention to the construction of the windows and cornice of the store front.

The exterior line of the show windows *B* may be on the line of the brick wall *a b*, or it may be permitted to project beyond the building line from 1 to 2 feet, as shown in Fig. 72 (*b*), according to circumstances. In either case, it is necessary to place the door frame of the entrance from 1 foot 6 inches to 2 feet 6 inches inside the building line *a b*, in order to secure a proper depth to the show windows. When the window front is on the building line, or when it is framed and finished down to the ground, as shown in the elevation (*a*), the corners of the window fronts usually consist of more or less ornate, turned columns or angle beads *C*, extending from the stone sill to the under side of the cornice which they appear to support. These columns are rabbeted on

the inside, in order to fit the sash above, and the paneling below.

The paneling is framed together and set in place between the rabbets in the columns, and small joists are carried across to receive the floor of the window. This floor finishes against the panel work on the inside, about 6 inches below the edge of the sash. The top of the window above the columns is finished with a wooden cornice, which also covers the steel beams supporting the upper walls.

114. The details of the construction of the cornice are shown in Fig. 73, where the steel girder is seen at *e*, consist-

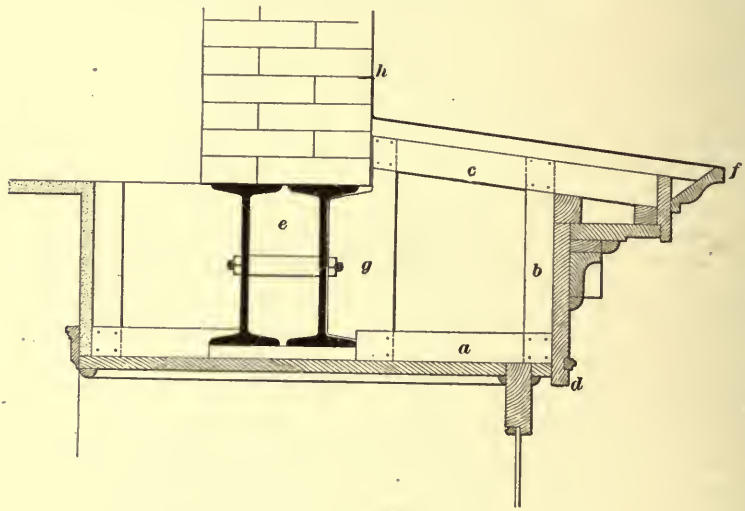


FIG. 73.

ing of two 12-inch beams bolted together, with the wood cornice *df* projecting from the face of the wall in front of them. This cornice is first formed in skeleton form, as shown by the pieces *a*, *b*, *c*, *g*, the last one *g* being cut to fit the form of the girder *e*, thereby giving the cornice a bearing over the opening. This piece is also anchored to the iron beam by means of bolts passing through the girder, and secured to the skeleton of the cornice by means of cleats nailed to the sides. The moldings and soffit of the cornice

are then applied to the skeleton work as shown, and the projecting roof is tinned, or flashed with copper, which in either case must extend up on the wall and enter the brick joints, as shown at *h*.

115. The entrance doors to the store are constructed in the same manner as the front doors described in Art. **44**, with the exception of the transom, which should be hinged on the bottom in this case, and provided with proper hardware to permit it to open inwards, in order to give ventilation to the interior.

When a show window projects from the wall of a building, but is not carried all the way to the ground in panels, as shown in Fig. 72 (*a*), the floor of the window is usually carried on ornamental wood or iron brackets, secured in the brickwork below the window, from which they project to the front edge of the framework.

116. There are many other details of joiners' work which have not been separately described, but the principles of construction upon which their framing is based are precisely the same as those herein discussed. The student must learn to apply principles rather than to memorize methods, and when a problem in any form of construction confronts him, he should not try to solve it in a certain manner, simply because it has always been done so before, but should endeavor to comprehend the conditions governing the case, and to study the form of joint and framing best suited to each particular case, and act intelligently, independent of traditional methods.

A SERIES

OF

QUESTIONS AND EXAMPLES

RELATING TO THE SUBJECTS
TREATED OF IN THIS VOLUME.

It will be noticed that the various Question Papers in this volume are numbered to correspond with the sections to which they refer, the section numbers being placed on the headline opposite the page number, as in the preceding sections. As in the case of the Instruction Papers, each section is complete in itself, the page numbers and question numbers beginning with (1) for each section.

2-37

MASONRY.

(ARTS. 1–285. SEC. 7.)

(1) (*a*) How is blasting performed? (*b*) What is meant by wedging rock?

(2) How is concrete made, and what are good proportions of its ingredients for foundations?

(3) (*a*) When are inverted arches necessary? (*b*) How are they usually built? (*c*) What are the objections to their use?

(4) (*a*) What are retaining walls? (*b*) State a good proportion of bottom thickness to height. (*c*) What is the object of stepping the back of a retaining wall?

(5) Describe fully the operations of needling and underpinning.

(6) (*a*) How are bricks burned? (*b*) What classes of brick are found in a kiln after burning?

(7) Why should brick not be laid in extremely cold weather?

(8) (*a*) What are brick-veneered walls? (*b*) How are they built and bonded?

(9) When the side walls of a building are carried up before the front walls, what should be done at the angles?

(10) Why should floor-joist anchors be attached near the bottom of the joists?

(11) Mention some methods of rendering the outside of brickwork waterproof.

(12) (*a*) State the requisites of good brick. (*b*) Would a brick which absorbed $\frac{1}{15}$ of its weight of water be suitable for exterior walls? (*c*) What should be the minimum crushing strength of good brick?

(13) (*a*) How is brickwork figured? (*b*) How are the number of bricks required for different thicknesses of wall generally estimated? (*c*) What is the usual practice in regard to figuring openings for common and pressed brick?

(14) What supports the hearths or fireplaces?

(15) (*a*) What are the intrados and extrados of an arch? (*b*) What is meant by a rowlock course of brick? (*c*) What is a *block-in-course* arch?

(16) How should footings partly on rock and partly on gravel be built?

(17) (*a*) How are stone walls bonded? (*b*) What should be the greatest area of wall to one header? (*c*) State why a continuous vertical joint in masonry is objectionable.

(18) What are the best methods of protecting the joints in brick belt courses from the action of the weather?

(19) (*a*) What is bond in brickwork? (*b*) What are stretchers, headers, closers, and coursers? (*c*) Describe English bond. (*d*) Describe Flemish bond. (*e*) Describe running or garden bond.

(20) (*a*) How are piles driven? (*b*) How should they be capped? (*c*) What are the sizes of piles? (*d*) Suppose the last blow of a 1,200-pound hammer falling 15 feet upon a pile causes a settlement of $\frac{5}{8}$-inch. What will be the safe load? (*e*) How are piles protected from wood-boring worms?

Ans. (*d*) 43,200 lb.

(21) Give description of methods employed to prevent the caving of excavations.

(22) What is the object in using bond stones and plates in brick piers?

(23) (*a*) What are party walls? (*b*) Why should they be thicker than ordinary outside walls?

(24) Why should brick cornices have small projections?

(25) (*a*) Why should flat arches be cambered? (*b*) If they are not cambered, what other mode of construction should be adopted?

(26) (*a*) What is pointing? (*b*) How should pointing mortar be made? (*c*) Describe the different kinds of pointing.

(27) (*a*) What is shoring? (*b*) How is it accomplished?

(28) How are areas drained?

(29) Give descriptions of the three forms of arches most frequently used to span openings in brickwork.

(30) How are floorbeams anchored to walls?

(31) (*a*) What is efflorescence? (*b*) What is used for cleaning brick walls?

(32) How should the different brick walls in the same building be carried up, and why?

(33) Why is it necessary that windows in different stories should be placed over each other?

(34) What is the best method of supporting floor joists on brick walls?

(35) How are face brick bonded to common brick in walls?

(36) What is a relieving arch?

(37) State the safe weights that different classes of brickwork will carry to the square foot.

(38) What are some of the causes of cracks in brickwork?

(39) How is terra-cotta furring attached to walls?

(40) When there are window openings in a wall carrying floorbeams, what should be the greatest proportion of width of openings compared with length of wall?

(41) What must be the thicknesses of brick walls for an apartment house 100 feet high, in New York City?

(42) How are hollow walls built and bonded?

(43) How should building excavations be staked out?

(44) (*a*) Give a description of how footings are proportioned to the weight they have to carry. (*b*) What is the principal point to be observed in proportioning footings? (*c*) Why may the pressure on the footings under columns be assumed as less than the calculations require?

(45) What precaution should be taken with brick used in warm weather?

(46) Describe some of the points to be considered in designing chimneys.

(47) Give a rule for determining the thickness of foundation walls.

(48) The pier footings of a building carry on each of 4 floors a dead load of 75 pounds per square foot and a live load of 100 pounds per square foot. The roof load is 20 pounds per square foot. The area supported by each pier being 15 feet square, what should be the size of the footing, if the soil will support 6,000 pounds per square foot?

Ans. 27 sq. ft., or 5.2 ft. square.

(49) What should be done with the space between the foundation walls and the bank of the excavation?

(50) When should steel or iron lintels be used?

(51) How are hollow brick bonded when used for furring?

(52) What are skewbacks?

(53) In masonry, what is meant by reveal?

(54) Give a description of spread footings, made of iron and concrete.

(55) (*a*) What are the component parts of brick? (*b*) What are the different processes used in making brick?

(56) How are area steps built?

(57) When is it proper to use sand piles for foundations?

(58) How are cluster piles connected to form foundations?

(59) What are the functions of mortar in masonry?

(60) (*a*) What purpose do damp-proof courses in walls serve? (*b*) How are they made?

(61) How should new walls be joined to old?

(62) (*a*) How is mortar prepared for use? What are the usual proportions of material (*b*) in cement mortar? (*c*) in lime mortar?

(63) Describe the methods of building sidewalk vaults.

(64) What kinds of pavements are usually used in or around buildings? Give a description of each.

(65) How is sewage disposed of when there are no public or private sewers?

(66) How are buildings adjoining a new building braced during the excavation for new work?

(67) By what method is the nature of soil under foundations discovered?

(68) Explain the methods employed to divert water from foundation walls.

(69) What are cribs or caissons?

(70) What precautions can be taken to prevent the percolation of water through cellar walls and floors?

(71) Give the best method of laying (*a*) common brick; (*b*) pressed brick. (*c*) How are mortar joints finished?

(72) (*a*) What varieties of soil or strata are found in excavating for foundations? (*b*) Which makes the best foundation? (*c*) What weight per square foot will different soils carry?

(73) What are groined vaults?

(74) Why are hollow walls preferable to solid ones?

(75) (*a*) What is grouting? (*b*) What are the objections to its use?

(76) (*a*) What are enameled bricks and their uses? (*b*) How do pressed brick differ from common brick?

(77) What is the safe *distributed* load on a piece of bluestone flagging 6 inches thick, 4 feet wide, and 8 feet between supports, taking the safe load as $\frac{1}{10}$ the breaking load?

Ans. 2.68 tons.

(78) What materials are generally used for mortar stains?

(79) (*a*) Explain the different characteristics of cement and lime. (*b*) Give a brief description of their manufacture.

MASONRY.

(ARTS. 1-264. SEC. 8.)

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(1) (*a*) State how changes of temperature affect the durability of stone. (*b*) Why is granite better than limestones and sandstones for damp situations? (*c*) Why should stone be laid on its natural, or quarry, bed? (*d*) What effect upon stone has rain falling through a smoky atmosphere?

(2) (*a*) What is ashlar? (*b*) State some of the points to be observed in laying it. (*c*) What are coursed and broken ashlar?

(3) (*a*) Describe porous tiling, and state in what way it is superior to dense tiling. (*b*) Where is dense tiling preferable?

(4) (*a*) In what respect does dolomite differ from ordinary limestone? (*b*) Mention some of the uses of marble. (*c*) Give a description of onyx.

(5) (*a*) Describe the method of applying the scratch coat of plaster. (*b*) Whence is its name derived?

(6) (*a*) How are the forms or molds arranged in building concrete walls? (*b*) How may apparent joints in such walls be made?

(7) (*a*) What are plaster boards? (*b*) Name some of their advantages.

(8) (*a*) What is the advantage in using slip sills? (*b*) How should the top bearing surfaces at the ends of lug sills be cut? (*c*) Why is the method referred to in (*b*) preferable to a pitched top surface the entire length of the sill?

(9) (*a*) What are *screeds?* (*b*) Describe the method of applying the brown coat of plaster.

(10) (*a*) Describe the construction of a fireproof pitch roof. (*b*) How are fireproof ceilings under pitch roofs supported?

(11) A sandstone lintel is 9 inches in depth, 6 inches in breadth, and 5 feet between the supports. What safe uniformly distributed load will it sustain? Ans. 2,268 lb.

(12) (*a*) How are plaster cornices made? (*b*) How is rough sand finish on plastering produced?

(13) (*a*) What are some of the advantages of terra cotta for exterior work? (*b*) How should pieces of terra cotta be tested before use? (*c*) How are cornices of terra cotta held in place?

(14) What is the reason for cutting washes and drips on projecting courses, window sills, etc.?

(15) (*a*) What should be the qualities of sand for plastering purposes? (*b*) What is the object of using hair in plaster?

(16) (*a*) Name some of the principal parts of an arch. (*b*) Why are the ring stones sometimes made of greater height near the springing line than at the crown?

(17) (*a*) What substances enter into the composition of lime mortar? (*b*) Describe the process of slaking lime. (*c*) What is meant by *popping* of plastering?

(18) (*a*) What are *tesseræ?* (*b*) How is the foundation made for tile floors in buildings having wooden floorbeams?

(19) (*a*) In cases where two arches spring from one column, what precaution should be made to prevent the lower voussoirs from becoming displaced? (*b*) About what

should be the smallest distance allowable between the extrados of an arch and the corner of a wall?

(20) (*a*) How should the ring stones of an arch be cut? (*b*) What thickness of joint is allowed for different kinds of work?

(21) (*a*) What is lathing? (*b*) What is the object of leaving spaces between the laths? (*c*) How is lathing fastened to brick or stone walls?

(22) (*a*) What advantages have tiled partitions over those made of brick or iron? (*b*) Why is porous tiling preferable?

(23) (*a*) How is the direction of the joints found for a three-centered, or false, elliptic arch? (*b*) Give the simple method for finding the direction of the joints of a true elliptic arch.

(24) (*a*) What are the best proportions of lime paste and sand for plastering mortar? (*b*) Give the quantities of materials necessary for 100 square yards of the first two coats of plaster.

(25) (*a*) Why should soft stone be hammered as little as possible in dressing? (*b*) State the order of building stones in regard to fire-resisting qualities.

(26) (*a*) What is the object of plastering? (*b*) To what two kinds of bases is plaster applied?

(27) (*a*) Why is brick backing for ashlar better than stone? (*b*) When very thin ashlar is used, how is it held in place? (*c*) In laying ashlar, should it all be of the same thickness (not height) or of different thicknesses, and why?

(28) (*a*) How are flat tile arches set? (*b*) How are floors laid over tile arches?

(29) Describe the process of making staff.

(30) (*a*) In what way does an end-method arch differ from a side-method arch? (*b*) Name some of the objections to the first mentioned arch.

(31) (*a*) What is the *carton pierre?* (*b*) How is scagliola made?

(32) (*a*) How can stonework be cleaned? (*b*) Describe Sylvester's process of protecting stonework. (*c*) How should linseed oil be applied for this purpose?

(33) (*a*) Name some of the advantages of the Roebling floor. (*b*) How is the ceiling under this floor held in position?

(34) From inspection of the table of Crushing Strength of Stone, give the highest and the lowest crushing strengths of each of the four classes of stone mentioned.

(35) (*a*) What is the objection to using a light-colored stone in a city where the atmosphere is very smoky? (*b*) What are the best stones to use in such cases?

(36) (*a*) Describe the Columbian floor, arranged for level ceilings. (*b*) About how much does it weigh per square foot?

(37) (*a*) How are stone or brick arches supported during construction? (*b*) Why are wedges used?

(38) (*a*) Describe some of the different kinds of arches deriving their names from the curves of the intrados. (*b*) What is a *stilted* arch?

(39) Give the safe strength of different kinds of masonry.

(40) (*a*) Mention some of the methods of testing stone. (*b*) How can the absorptive power of stone be determined?

(41) (*a*) When are segmental tile arches used? (*b*) What are the advantages of the Fawcett ventilated floor?

(42) Describe (*a*) the Venetian-Gothic arch; (*b*) the Moorish arch.

(43) What is the Ransome system of concrete construction?

(44) What is rough cast, and how should it be applied?

(45) (*a*) What provision is sometimes made in laying concrete walls to allow for expansion and contraction? (*b*) How is the surface of such walls finished?

(46) (*a*) How is rubble masonry usually measured? (*b*) How is ashlar measured? (*c*) How are moldings, etc. measured?

(47) (*a*) Mention some advantages of natural wall plasters over lime plaster. (*b*) What is Keene's cement?

(48) Mention some points in connection with plastering requiring the inspector's attention.

(49) (*a*) Name the constituents of granite, and mention some of its valuable qualities. (*b*) What are the differences between granite, syenite, and gneiss?

(50) What is whitewash, and why is it valuable?

(51) (*a*) How are girders and columns fireproofed? (*b*) Give some requirements of the Chicago building law in regard to column protection.

(52) Give the weight per cubic foot of the several kinds of building stone.

(53) Mention some uses of metal lath in wood construction.

(54) (*a*) What is "coarse" stuff? (*b*) Why should not sand and hair be added to the lime directly after the latter is made into paste?

(55) (*a*) Describe the plumb and how it is used. (*b*) What are floats used for?

(56) Describe the method of laying floor tiling.

(57) Describe (*a*) the crandall; (*b*) the patent hammer; (*c*) the bush hammer. (*d*) Mention some of the different kinds of chisels.

(58) (*a*) What are some of the defects in building stone to be guarded against by the inspector? (*b*) What is patching?

(59) (*a*) What is quartzite? (*b*) Why is a stone containing iron pyrites objectionable for outside construction?

(60) (*a*) Describe the manner in which a good rubble wall should be built. (*b*) What is coursed rubble?

(61) (*a*) What is a draft line? (*b*) What is the difference between drove and tooled dressing? (*c*) What is meant by "vermiculated"?

(62) Describe (*a*) the Roebling lath, and (*b*) the expanded metal lath.

(63) (*a*) How should pointing mortar be made? (*b*) How should it be applied, and how are the joints finished?

(64) (*a*) What is an entablature? (*b*) What is a pilaster? (*c*) In setting the pieces composing a column, what precautions should be taken?

(65) (*a*) Mention three classes of stone masonry. (*b*) What are the objections to convex and concave bed joints in stonework?

(66) Describe the construction of the Metropolitan floor.

(67) (*a*) What are plaster grounds, and what is their usual thickness? (*b*) Mention some reasons why the plasterer should examine the walls before applying the plaster.

(68) (*a*) Name some of the advantages of metal lath. (*b*) How is metal lath applied to woodwork?

(69) (*a*) Mention some methods of strengthening stone lintels. (*b*) What is a relieving lintel?

(70) (*a*) What is gauged stuff? (*b*) What is stucco?

(71) (*a*) Describe the process of machine mixing of concrete. (*b*) What are good proportions of cement, sand, and crushed stone for concrete walls?

(72) (*a*) What are quoins? (*b*) How should jamb stones be arranged?

(73) (*a*) Mention some things to be considered in putting on lath. (*b*) What is the objection to setting laths vertically on a wall?

(74) (*a*) What are templets? (*b*) What should be their least thickness?

(75) How should coping on gables be secured in place?

(76) (*a*) What are some of the qualities of a good lath? (*b*) What is the usual size of laths? (*c*) What is sheathing lath?

(77) (*a*) How is plastering measured? (*b*) What is the average cost of plastering?

(78) (*a*) How is plaster of Paris made? (*b*) Why is it used in plastering mortar?

CARPENTRY.

(ARTS. 1–234. SEC. 9.)

---

(1) How should the first course of shingles be laid on the roof?

(2) When is it necessary to truss a partition?

(3) What is the essential difference between the method of flashing hips and the method of flashing valleys?

(4) (*a*) What is meant by a *single* floor? (*b*) What is meant by a *double* floor? (*c*) How is each laid?

(5) (*a*) What is a water-table? (*b*) For what purpose is it intended?

(6) What woods are best suited to the rough framing of a house?

(7) How may dry rot be prevented in wood columns?

(8) (*a*) Into how many divisions are trees classified according to their methods of growth? (*b*) What are they called? (*c*) Which furnishes the best wood for building purposes?

(9) (*a*) How should the boards of a veranda floor be laid? (*b*) How are the joints rendered water-tight?

(10) When is it necessary to truss door or window openings?

(11) Why is especial care required in laying the roof at the eaves?

(12) What is matched flooring?

(13) Describe the method of determining the curve to which the edges of beveled siding must be worked in order to properly fit the surface of a circular tower.

(14) What woods are best suited for damp situations not in contact with the earth?

(15) In slow-burning construction, how are the floor-beams tied together throughout the building?

(16) What are the inner layers of the heart wood of a tree called?

(17) How are the valley rafters treated in a gable roof which intersects with a main roof of greater height?

(18) What are dormer-windows?

(19) (*a*) How far apart are partition studs usually placed? (*b*) Why?

(20) What is a chamfer?

(21) Why are splines used in plank floors?

(22) What woods are best suited to situations in contact with damp soil?

(23) What are medullary rays?

(24) (*a*) What is a gable roof? (*b*) What is a gambrel roof?

(25) (*a*) What are wood centers? (*b*) How are they constructed?

(26) How is the sill of a house laid on the foundation wall?

(27) On what should the feet of studs rest (*a*) when the partition runs across the beams? (*b*) when it runs parallel with the beams?

(28) (*a*) What is a trimmer-arch center? (*b*) How does it differ from an ordinary center?

(29) What hard wood is well suited to a dry, well ventilated position?

(30) (*a*) What is a hip roof? (*b*) What is a Mansard roof?

(31) What wood and what sizes of plank are best suited to floors in slow-burning construction?

(32) What are the best seasons to cut trees for lumber?

(33) What are spherical pendentives?

(34) What is the thickness of a mortise in proportion to the timber in which it is cut?

(35) Why is it necessary to have the same thickness of sill under all partitions and walls of the same house?

(36) How are lath secured in the angles of a room?

(37) (*a*) What is a dome? (*b*) How is it framed in wood? (*c*) How is it covered?

(38) (*a*) What is Carolina pine? (*b*) Is it as durable as Georgia pine?

(39) How are partitions formed in slow-burning construction?

(40) At what age do trees arrive at their maturity?

(41) What is a groined ceiling?

(42) In braced-frame construction, how are the interties framed with the corner posts, when the floorbeams are parallel with the front of the building?

(43) Why is sheathing usually laid diagonally?

(44) How are the second-story beams carried in balloon-frame buildings?

(45) For what purpose was slow-burning construction first introduced?

(46) (*a*) What wood makes the best piles? (*b*) Why?

(47) What is the difference between braced-frame construction and balloon-frame construction?

(48) In slow-burning construction, how are the beam ends protected when they rest in a brick or stone wall?

(49) What are cup shakes?

(50) What is quarter-sawed timber?

(51) (*a*) How is the steel square used to mark the cuts of rafters? (*b*) Explain the use of the fence as applied to the steel square.

(52) What two methods are used in spacing the studding of exterior walls?

(53) (*a*) Is hemlock a good material for first-class framing? (*b*) Why?

(54) What is a fish joint?

(55) What are fungi?

(56) Why are shingle lath preferable to close boards as a roof covering under shingles?

(57) How should lumber be piled in order to season properly?

(58) Why should the ends of beams be cut on a slant when they rest in a brick wall?

(59) What is the simplest joint between two pieces of wood?

(60) What is a mortise joint? (Describe in detail.)

(61) What is the characteristic difference between slow-burning construction and ordinary wood construction?

(62) How are the tops of floorbeams maintained at a uniform level in a building?

(63) Why is it necessary to set jack-rafters in pairs, one each side of the hip or valley?

(64) (*a*) What do the figured dimensions of doors and windows represent on architects' plans? (*b*) What must these dimensions be in the rough frame openings?

(65) (*a*) What is flashing? (*b*) When is it used?

(66) (*a*) What are brick nogs? (*b*) When are they used in a frame building?

(67) What are plaster grounds?

(68) What is the general system employed in slow-burning construction?

(69) What wood is best adapted to tanks and other vessels constantly filled with water?

(70) In slow-burning construction, why are iron beams sheathed with wood?

(71) (*a*) What are heart shakes? (*b*) What causes them?

(72) What is a liberal proportion of leader to roof area?

(73) (*a*) What is the difference between beveled siding and novelty, or patent, siding? (*b*) Which is the better?

(74) What are furring strips?

(75) What is the ultimate object of the system of slow-burning construction?

(76) What are the best woods for shingles?

(77) What are (*a*) headers? (*b*) trimmers? (*c*) tail-beams? (*d*) How are they joined together?

(78) What is rot in timber?

(79) How are walls lathed and plastered in slow-burning construction?

(80) (*a*) What are purlins? (*b*) How are they cut to miter?

JOINERY.

(ARTS. 1–116. SEC. 10.)

---

(1) What method is generally adopted where several stiles and rails of a door are to be veneered at one time?

(2) Describe in detail the method of veneering a small cylinder.

(3) In bending wood by saw kerfing, how may the proper spacing of the saw kerfs be determined?

(4) Show the method of obtaining the length and shape of the soffit of a semicircular window in a straight wall, the jambs of which splay equally all around from the center line at an angle of 30°. The wall is 2 feet thick, and the window 3 feet wide on the inside; scale, $\frac{1}{2}$ inch = 1 foot.

(5) A semicircular-headed window in a curved wall is 4 feet 6 inches wide, and the wall is curved with a radius of 8 feet. Show the method of developing the window head, the wall being 2 feet thick with a 4-inch reveal, and the jambs of the window parallel. Scale, $\frac{1}{2}$ inch = 1 foot.

(6) How are the moldings on sash bars treated where they intersect?

(7) How is the parting strip of a window frame held in place?

(8) How may the widths of the stiles and panels of a wainscot be determined, when the number of the panels and the length of the room are known?

(9) What are *bases* or *skirtings?*

(10) What is the effect of shrinkage in mitered joints?

(11) Describe the process of joining two thin veneers.

(12) How should the cores of veneered doors be prepared?

(13) (*a*) What five methods are used to bend wood? (*b*) Which is considered the best?

(14) (*a*) Make a diagram showing the method of obtaining the bevels for an octagonal pyramid whose base is 1 inch on each side and the perpendicular height to the apex is 4 inches. (*b*) Show how the bevel should be held to test the angles.

(15) How should the weights of the upper and lower sashes be proportioned?

(16) What are French windows?

(17) How is the amount of bevel determined, necessary to enable a folding door to open and close readily?

(18) What is the first step necessary in determining the relative sizes of the panels and muntins of a line of wainscoting?

(19) (*a*) What are *architraves?* (*b*) How are their upper edges joined?

(20) How should the members of a dovetail joint be proportioned?

(21) In a pantry (*a*) about what should be the height of the service table? (*b*) about what should be the depth of the dresser? (*c*) about what should be the size of a dumb waiter required for the sole purpose of serving meals?

(22) (*a*) What is a *caul?* (*b*) How is it prepared for use?

(23) In dovetailing a hopper of the dimensions given in question 32, how should the dovetail pins be cut?

(24) How may the sash cord be secured to the sash?

(25) What quantity is a box of window glass assumed to contain?

(26) How are the pockets for sliding doors framed?

(27) Describe the positions of the grounds necessary for different styles of wainscotings.

(28) What method is adopted to prevent broad, plain surfaces from warping?

(29) Describe the common dovetailed joint.

(30) In hanging doors, what details must be taken into consideration to determine the proper projection of the hinges?

(31) For what reason are hard-wood veneers generally used?

(32) Make a diagram showing the method of obtaining the miter cuts for a square hopper which is built of material 6 inches thick, 4 ft. $\times$ 4 ft. on top, 2 ft. $\times$ 2 ft. on the bottom, and 2 feet deep. Scale, $\frac{1}{2}$ inch = 1 foot.

(33) Describe the operation of hanging the sash in a window frame.

(34) What consideration generally determines the dimensions of window sashes?

(35) Describe a device for securing the stiles and rails of a door, other than the mortise and tenon.

(36) What is the best method of securing a long, plain, unpaneled wainscot against warping or shrinking?

(37) State the distinction between carpentry and joinery.

(38) Where is the half-lap dovetail joint frequently used?

(39) What conditions must be taken into consideration in framing outside and inside blinds?

(40) What are *veneers?*

(41) Show the method of obtaining the length and shape of the soffit of a semicircular window in a concave wall, the jambs of which splay out at an angle of 30° with the center line of the opening, and the soffit of which, at the top of the opening, is level. The wall is 1 foot 6 inches thick, the opening 3 feet wide, and the radius of the curvature of the wall 7 feet to the outside line. Scale, $\frac{1}{2}$ inch = 1 foot.

(42) What is *splayed* work in joinery?

(43) How are the mortise-and-tenon joints secured in a sash?

(44) How is a water-tight joint secured between the stone sill and the wooden sill of a window?

(45) Where should the glue be applied in mortise-and-tenon joints?

(46) What is a *dado?*

(47) (*a*) What is the characteristic difference between the joints made use of in carpentry and those used in joinery? (*b*) Into what two general classes are these latter joints divided?

(48) For what reason is the blind-dovetail joint used?

(49) How are inside blinds hinged to insure their unobstructed closing into the blind box?

(50) It is required to bend a pine plank around a cylinder whose diameter is 15 feet. What thickness of plank may be used without steaming or other preparation?

(51) Show the method of obtaining the length and shape of the soffit of a semicircular window in a curved wall, the jambs of which window radiate from the center, from which the curve of the wall is struck. The wall is 2 feet thick, the opening 4 feet wide on the inside, and the radius of curvature of the wall 6 feet to the inside. Scale, $\frac{1}{2}$ inch = 1 foot.

(52) (*a*) Show the method of preparing a face mold for the top rail of the sash to be inserted in the window frame described in question 5. (*b*) How should this face mold be applied?

(53) How are the meeting rails of a sash made?

(54) What is a *mullion?*

(55) What are *relishes* in framed work?

(56) (*a*) Why is a chair rail used in an apartment? (*b*) How high should it be placed?

(57) (*a*) What process is necessary to secure a first-class job of gluing? (*b*) How can the quality of glue be tested?

(58) Describe the method of mitering a straight molding and a circular molding when the two intersect at an acute angle.

(59) (*a*) What is meant by *backing a veneer?* (*b*) Describe this process of bending wood.

(60) Show by sketch the details of a cornice for a store front.

INDEX.

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